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How to Make a Motion Picture of the Water Works

By W. Victor Weir

WATER is taken for granted. It is the stuff that rains on us. It also comes out of the faucet when the handle is turned. The water works are taken for granted, too; that is, until some trouble, which gets into the newspaper, occurs; until taxes or water rates must be raised to provide some important plant improvement; until the pressure drops on a hot afternoon; or until the water bill arrives. Four times out of five, when Mr. Average Citizen thinks of the water department or the water company, as the case may be, he is irked by something. He seldom realizes what he and his fellow citizens owe to the men who constructed and operate the water works.

We all have something to sell—our labor, our training, our ability, our knowledge, our services. A human parasite is a person who has nothing to sell; yet even parasites endeavor to sell their personality to retain their friends, and their jokes to maintain their own self esteem. There is no stigma attached to selling, except when it is crudely done.

The water works management has something to sell. The tangible goods are water and fire hydrant service, and for these the payment is money. Also, there are certain intangibles—good engineering, careful control, constant supervision, efficient operation, etc. The

A paper presented on November 15, 1940, at the Missouri Valley Section Meeting, Omaha, Neb., by W. Victor Weir, Superintendent, St. Louis County Water Co., University City, Mo.

payment desired for these intangible services rendered by the water works management and employees is also intangible, and might be termed understanding and confidence by the public which receives the services—the understanding of the important and vital part played by the water works in community life and the confidence that the water they receive is the best that good physical equipment and efficient, capable men can produce.

Water works men are making conscious efforts to obtain the understanding and confidence of the people they serve. Grounds are beautified. Buildings are designed to be pleasing to the eye. Building interiors are kept hospital clean. School classes are invited to inspect the plant. Talks are made to service and social organizations. Recently, motion pictures have been prepared to be shown in classrooms and at luncheon meetings.

Publicity Value of Motion Pictures

The motion picture is an excellent vehicle for carrying the water works message to the public. The physical conditions under which a movie is shown insure a high degree of attention. The pictures on the screen are the only thing in the room to attract visual attention. The spoken message accompanying the pictures holds auditory attention. From a psychological standpoint, the spectator is in a setting which is ideal. He does not have to read to comprehend the message; nor does he have to conceive words as he would at a lecture. There is no distracting element.

The water works story provides all the elements necessary to an interesting motion picture. The processes involved, the human story of the use of water, and the colorful beauty to be found around the plant make a very dramatic story. A motion picture properly made should be far from prosaic.

Choice of Amateur or Professional Personnel

The question: "Should a professional be hired to make a motion picture of the water works, or should the project be undertaken by some one of the water works personnel?" may be answered "Yes." A successful picture can be made on either basis. A film made by an industrial motion picture production studio will be better than a home-made one. The finish will be better. Laps, dissolves, and other flourishes will be available. The photography will be of the

best grade. A sound track can be made to accompany the pictures. All in all, the results should be nearly 100 per cent. On the other hand, amateur moving picture making has progressed to the point where very creditable pictures are being turned out by hobbyists. The equipment and film available to amateurs are high grade, easily handled, and reasonable in cost. Another factor exists—a good home-produced film will have a spectator interest that a professionally produced film of unquestioned higher quality will lack. It should possess a warmth that can only be caught with difficulty by the professional. Then, too, the cost of a professional job may dictate a home-made movie.

Specifications for Amateur Production

The specifications of a home-produced movie of the water works are that: (1) it should be suitable for audiences of 10 to 200; (2) the picture should be 20 to 30 minutes long; (3) it should be interesting to persons of all ages; and (4) it should compare favorably with a professional job.

The first specification dictates that the size of the film should be 16 mm. The smaller popular 8-mm. film is not recommended, since it is difficult to project it successfully for the large audiences which might wish to view the picture. The projected image should be 45 by 60 inches or larger.

The second specification is set by the time usually available for the showing of such a film. For service club and classroom use, the film length of between 20 and 30 minutes is most satisfactory. The 16-mm. film would therefore have to be from 400 to 600 feet in length.

The third specification requires that the picture be of general interest to both children and adults. The picture should be elementary enough to hold the interest of children in the sixth or seventh grades, yet contain no items which would be prosaic to adults. Sound should be used in conjunction with the pictures. The silent motion picture catered to only one of the human senses. The sound motion picture caters to two, sight and hearing, and is, thus, much more interesting and effective. For the water works movie, it is suggested that the accompanying sound be the spoken voice of one of the water works employees who would be delegated to be present at each showing of the film. Where the auditorium is large a public address system should be used to amplify the voice.

Suggested Introductory Sequence and Script

PICTURE SEQUENCE	TIME	SCRIPT
	sec.	
Titles	15	(no voice while title is shown)
Globe revolving slowly	5	We are all familiar with water. Water covers three-quarters of the surface of the earth.
Cumulus clouds	4	Clouds form from water vapor in the sky.
Dark cloud bank	3	The clouds which shield us from the glaring heat of the sun are the protecting shield which allows life on the earth.
Rain falling on pavement (Use hose spray, if necessary, in making close-up shot)	5	Rain falls as a beneficent gift from the heavens.
Pond or lake	4	Ponds and lakes bejewel the earth's surface.
Creek or river	5	Creeks and rivers course their ways to the sea.
Colorful sunset	4	Water vapor paints the gorgeous sunsets.
Fresh fallen snow	4	Snow lays a pristine cloak over the earth.
View of your city from top of water tower	4	Today we live in cities, great and small, and we know water by the ways we use it.
Another view of your city	4	
Sweating man drawing and drinking a glass of water	5	We think of it as something to drink, if we can't get anything else.
Steaming pot on stove	3	We cook with it.
Mother and daughter washing dishes	4	We wash dishes with it.
Baby splashing in bathtub	6	We bathe the baby. Saturday night now occurs every day of the week.
Sheets billowing in wind	3	Our clothes are made white.
Sprinkler revolving on lawn and boy holding hose	5	In the summer when Mother Nature forgets us, we keep our lawns and shrubbery green.
Pull carrots from ground and rinse in bucket of water (Close-up, hand and carrots only)	5	Our vegetables are solid and luscious, thanks to irrigation.
Vase of flowers, revolving slowly	5	Water furnishes enjoyment—beautiful flowers in a vase of water.
Aquarium	4	Iridescent fish in an aquarium.
Children in pool	4	Human fish in the most enjoyable of summer sports.
Diver springs from board	3	
Fire destroying miniature house model	6	But we also have fire, benefactor and destroyer.
Fire truck leaving station	4	Highly trained fire fighters are on constant and alert duty.
Fireman opens hydrants and water spurts from nozzle	6	The silent unobtrusive fire hydrant is always in readiness for use in fighting fires.

The fourth specification, that the production be a creditable one, is undoubtedly the primary reason for the writing of this paper. As preface to the paragraphs which will follow, it should be stated that the planning, photographing and editing of the film can be undertaken by anyone who has worked at either still or motion picture photography as a hobby, provided that he follows certain general rules which will be mentioned.

Preparation of Scenario

The preparation of the scenario or story outline is the initial problem. The object of the movie is to portray the importance of water to modern living, the benefits of a public water supply, and particulars regarding the individual water works in question. The story outline should be planned with those objects in mind. After the story outline is selected, the filming, until the necessary picture sequences have been obtained, should be undertaken. These sequences should then be pieced together in the desired order to make the complete motion picture story. The general form of such a scenario, showing the relation of the subject material to the script, might be as shown in the "Suggested Introductory Sequence and Script" on page 204. This suggested general introduction takes precisely two minutes. It might be lengthened to three or four minutes if desired, as the general treatment of the subject of water is of great interest.

The picture should then progress logically through the succession of processes followed by the water in its progress from the source of supply to the final pumping operation. Colored line diagrams will greatly assist the spectators to visualize the path of the water through the plant. Shots of the various laboratory procedures accompanied by oral descriptions of their frequency and importance in insuring uniform chemical characteristics and acceptable bacterial quality will emphasize the care exercised in supervising the water treatment.

Also to be included are pictures of certain features of the distribution system: a line diagram showing the network of mains, the standpipes or elevated tanks with an explanation of their functions; the office building and employees at their desks; the service trucks moving across the line of vision; and possibly a minute or two on the laying of pipe to show, for instance, how bell and spigot pipe is jointed.

To end the picture without an anti-climax, some summary should be made. By utilizing short pieces of film cut from preceding sequences, one may, after showing a panorama view of the plant, follow up with a succession of flashbacks, showing basins, filters,

pumps, laboratory views, elevated tanks, fire hydrants being flushed, etc. The last shot could appropriately be a small child being given a drink of water from the kitchen faucet, or a perspiring man drinking a glass of water and drawing more.

Techniques of Photography

The technique of filming such a picture is necessarily a problem to the average water works man. There will usually be willing and capable amateur assistance available for the asking, if it does not exist in the water department. There are, however, several tried and true instructions regarding movie taking which will bear repetition.

First, it should be realized that the medium is that of motion, not still pictures. Wherever possible there should be motion in the shots. Don't just show a filter—show it being washed. Show the basins, and also show the sludge being removed from them. Have all pieces of machinery in the laboratory in motion, the stirring machine operating, the hoods being opened and closed, the microscope being used. Show the color change of ortho-tolidine and starch iodide tests. Motion is action, and action is dramatic.

Second, remember that the camera is to record action, not provide it. Have it on a tripod always. Show panoramas only when absolutely necessary, and then slowly and with three seconds of stationary filming at the beginning and two seconds at the end.

Third, remember that several short shots from different angles are more interesting and dramatic than one prolonged shot. Four to six seconds is a good length, except where more time is necessary to show a sequence having sustained interest. Check this by timing the lengths of shots at the next news-reel or commercial picture you see.

Fourth, close-up shots are usually of more interest than distance views. There is less distracting material in them. They should be used frequently to good advantage.

Fifth, use a proven light meter or an exposure guide for all interior and most exterior exposures. Don't guess at exposures unless the cost of film is no object.

Sixth, take advantage of all the beauty afforded, by the use of color film. Make the plant exteriors when grass is green and flower beds are in full bloom. If transition shots are required between any of the film sequences, they might be made by showing close-up shots of vivid, individual flowers, while the narrator introduces the audience to the next scene.

Equipment

The equipment necessary to film a water works movie may already be available or may be borrowed or purchased. The essential items are:

(1) *Camera:* The camera should be of the focusing type, with, preferably, an f.1.9 lens. The fast lens is desirable because of the number of interior shots to be taken in the plant and laboratory. The focusing camera can also be used to make the titles from neatly lettered colored cards or lettered photographs.

(2) *Tripod:* This is essential for making rock-steady pictures. It will prevent audience sea-sickness.

(3) *Exposure:* A proven light meter is a good tool, although the "Kodachrome" exposure guides, made by the Eastman Kodak Company are thoroughly reliable.

(4) *Lights:* Because of the interior views which must be taken, artificial lights are necessary. Four No. 2 photoflood lamps in reflectors should provide all the light necessary. Take the indoor shots at night with Type "A" film. If taken in the daytime, the pictures will have a blue cast due to the daylight.

(5) *Film:* For outside views, use regular 16 mm. "Kodachrome"; for inside views, use type "A" "Kodachrome." Although this film is approximately twice as expensive as black and white film, it is incomparably superior. If time and trouble are to be expended in making a water works movie, the best film obtainable should be used. The "Kodachrome" original will remain in good condition for several years, in which time it should have become outdated and a new film made. The cost of film will be practically all of the cost involved if the film is a water works product. The retail list price of 16 mm. "Kodachrome" film is $8.00 per hundred feet. For a finished film, 400 feet long, with a showing time of slightly less than 20 minutes, it should be necessary to expose 600 feet of film. Film wastage should be from one-third to one-half of the finished picture length.

Editing and Consolidation

After the filming is completed, the movie is ready to be made into a success. It will be impossible to shoot the film in the exact sequence desired in the finished product. Many scenes, although perfect photographically, will have to be cut to proper length to obtain the right tempo. Transition shots will have to be inserted. Any sequences which have been improperly exposed must be retaken and

spliced in. The normal amount of film to be discarded should be from one-quarter to one-third of the film exposed. By severe editing, cutting down the scenes to proper length, splicing them together to obtain a satisfactory tempo, the film will be made worthy of the attention of the audiences it is to have and worthy of the water department or water company it portrays.

When editing is completed, the script must be revised to fit the film. After projecting the picture a few times, during which showings an effort should be made to speak the accompanying vocal story, the script should be dictated to a stenographer. The stenographic draft should then be revised to produce the finished script. As stated before, for occasional showings, where a water works employee is present, the spoken sound will be practically as effective as would sound on film. A great advantage of the spoken story is that it can be varied, depending upon the age group to which the film is shown.

The production of a water works movie will be both interesting and constructive. It should fill the important gap which usually exists between a water works management and the public it serves.

Discussion by *John E. Kleinhenz.* * Any discussion of Mr. Weir's paper must of necessity be limited to a description of personal experiences, as the paper is thoughtfully and thoroughly presented.

Mr. Weir's statement that "the motion picture is an excellent vehicle for carrying the water works message to the public" could be embellished by several streamlined superlatives and still be an understatement. At the Indianapolis Water Company the members of the staff are firm believers in the motion picture as a means of bettering public relations, and as evidence of their belief present an array of three pictures—the latest completed last November—which tell the story of the city water supply. Two other films have also been produced, one portraying the beauties of water and its surroundings and the other, a panorama of the construction of an elevated water tank, started as an engineering study and wound up as a supplementary subject for regular audience showings.

The company's first venture into the cinema field came in 1933 with "Behind the Water Front," a black-and-white film. In 1935, "Water Colors" was produced. As its name implies, it was filmed in color and, it is believed, pioneered color photography for educational water movies. In November, 1940, the third picture—

* Publicity and Advertising, Indianapolis Water Co., Indianapolis, Ind.

"The Waterway to Health"—emerged from the cutting room and this too was filmed in color.

As Mr. Weir pointed out, the water works movie can be made either by a professional or by photographically-inclined amateurs in the company personnel. The latest film was a product of a combination of the two methods—the writer being a camera hobbyist who fortunately was teamed with the same professional who produced all of the other pictures. In this way, amateur exuberance was tempered by professional experience to give the picture benefit of the advantages of both.

Cost Data

A study of the costs of these various productions might be of interest to those contemplating the task of making a picture. Accurate figures on the earlier pictures are not available as the expenses of company personnel and some incidentals were not separated. The black-and-white pioneer might be estimated at $600 or $700, and the first color film at $800, neither including any employee time.

The writer's initial effort was the color movie of the tank erection in 1939, which, as previously mentioned, traced the progress of the work from foundations to placement in service. No scenario was needed. It was merely necessary to be on the job when the next step in the work was taking place. Editing, too, was easy, consisting only of cutting the film until the story flowed smoothly. Perhaps that remark should be qualified by the assertion that it is now, in retrospect, and in comparison with the hours spent on the latest picture, that the editing seems relatively simple.

The total cost of the tank erection production was $292.60, of which photographing and editing took $168.25 and film and titles $124.35. The costs for time and transportation in the first figures include both that of the professional and of the writer. The quantity of film scrapped in such a record film was held to a minimum. It is the type of film that could be taken by an amateur equipped with a turret-head camera and the proper editing equipment, as few special effects were found necessary.

Production of "The Waterway to Health" offered many more problems, foremost of which was the task of presenting the same subject—the Indianapolis water supply—in a manner different from that already effectively employed in the two previous films. It was essential to avoid triteness and repetition and yet to emphasize the vital parts of the distribution system.

Tentative plans for the picture had been drafted and some pipe-laying scenes "shot" by the writer's predecessor. It was deemed both advisable and economical to utilize this film in the outline if possible, though naturally the writer's ideas, conception, and treatment of the theme differed somewhat. As the outline progressed, the picture was directed at the illustration of the dangers ensuing from unguarded water sources in a city adequately equipped to give every citizen the advantages of a modern water supply.

Before citing the costs of the picture, perhaps a general sketch of its scenario might be of advantage. The story starts with scenes illustrating the water cycle; traces the early ways of getting water, from pioneer stooping to a creek, to the well-sweep and the windlass well in a forest stockade; shows the effect of water-powered grist and saw mills upon community growth; depicts the types of pumps that were used as families settled farther from the creek or the town pump; shows the first home outlet, the yard hydrant, using water from a centrally-pumped supply; then brings the picture home with a shot of the cascades on the Soldiers and Sailors Monument in downtown Indianapolis. Following this introduction the story traces the passage of water from the river to the settling basins, filters, and pumping stations; the expansion of water mains correlative to city growth; and a digression to show some human interest shots of swimming, circus, football (shower-room), sprinkling, and fire-fighting, all of which emphasize the personal and civic pleasures, protection, and advantages ensuing from a modern supply. The outline of dangers from fire led naturally into pointing out the dangers from contaminated wells. Fortunately, in this connection, it was possible to photograph some "slums" scenes which aptly portray the deplorable conditions resultant from backyard pumps located a few yards from outside privies, garbage containers, etc., and open to all kinds of pollution and contamination.

From this point, the picture proceeded to depict the purification department's chemical and bacteriological laboratories where the story of careful treatment and stringent tests and analyses which enter into the production of a city's water supply today is told. Finally, the closing sequence demonstrates the effects of using such a safe supply, showing a healthy, happy family going about its daily chores without worry—bathing, cooking, laundering, and, of course, caring for the baby. The emphasis placed on "safe water giving the baby a better chance to reach manhood healthy of body" fades

into a shot of a little girl writing "The End" on a school blackboard bearing the words "Safe Water for Health."

Although the cost of "The Waterway to Health" was greater than any of the other pictures, it would not seem to be excessively so if the cost of company personnel had been included in the previous figures. The final figure is approximately $1,250, which might be itemized roughly as follows:

Professional photography	$275
Film used by professional	225
Professional editing	275
Special effects done elsewhere	25
Titles	18
Drawings, maps, etc.	30
Film used by amateur	70
Amateur's time expense	232
Company transportation cost	43
Acting, costumes, etc.	47
Enlargements for publicity	5
Humidor and reel	5
Total	$1,250

Although the film is considered complete in its present form, there will undoubtedly be additional small expenses from time to time to keep the picture up to date. For instance, insertion of the latest steps in the construction of the new water treatment plant, a "good" fire scene, or such timely subjects as would make the film better by their inclusion are planned.

The item of film used by the amateur—the writer—warrants explanation. The company purchased a camera for his use in getting such scenes as the above-mentioned, since it is not always possible for the professional to be reached at the proper moment. The camera is always available, and the writer has been able to secure some scenes of clouds, sprinkling, construction work, etc., which would not again present themselves with just the right lighting, angle, and other essentials of good photography.

The quest for a "good" fire is as yet unsuccessful, although fires at all hours of the day and night have been filmed.

In another connection, too, the company camera has served to improve the continuity of the picture. In some costume scenes the professional focused his camera from one angle, the writer from another, and the two "shots," simultaneously obtained, gave pictures that blended together easily and effectively in the editing process.

In the final assembly of the film, it was found that more than 2,900 ft. of film was left after discarding all which was not usable because of technical faults. As a picture of about 30-minute length was all that was required for presentation before luncheon clubs and school classes, it was necessary to reduce the film to about 850 ft., including titles, or about 800 ft. of actual photography—25 per cent of what was available. It was, of course, expected that some film would be wasted, but it was thought better to shoot first than to be sorry afterward.

The first editing was wholesale elimination, then a few feet at a time, finally dwindling down to a frame here and a frame there to tie the action together a little more smoothly. Now, after obtaining audience reactions, spots, here and there, which could be bettered by careful manipulation of the scissors are becoming evident.

Exhibition

"The Waterway to Health" is a 16-mm. silent film, but a sound projector is used in showing it. As Mr. Weir mentioned, there are many advantages in presenting such a picture with accompanying remarks by one of the company personnel. The writer utilizes a microphone and the projector public address system in his narration. It has been found that sitting beside the projector and using the "mike" does not distract the attention of the audience as much as standing to one side of the front of the room and speaking without benefit of "P. A." system. Also, when several showings of the film must be made consecutively, as at an all-day session at a high school, the saving on the narrator's vocal chords is tremendous.

Since 1933, the three main pictures have been shown to 525 audiences with a total of approximately 55,000 listeners. The majority of these showings were in schools, so it is felt that the groundwork in educating the youth of the city will have its effect in bettering public relations when these young people become individual consumers.

There is a possibility, however, which water works officials should consider, that a full and frank explanation of the vital points of the system might not be the best policy under conditions resultant from today's unsettled outlook. If it is thought advisable to discourage the casual visitor to our plants because of national defense measures, would it not be at least inconsistent to take the plant right to the person who needed such information for detrimental purposes?

Flood-Forecasting Service in Pennsylvania

By John W. Mangan

IT SEEMS probable that flood warning in Pennsylvania extends back long before the advent of the white man. From references in early writings we know, at least, that the Indians gathered knowledge concerning the behavior of the streams along which they lived, and subsequently passed this information on to the early white settlers.

Settlement in Pennsylvania began along the natural waterways and the important cities and towns of today, with few exceptions, are on the sites of the first occupancy. As the communities grew and encroached more and more upon the stream channels, the resulting damage from floods tended to become greater. This misled many into believing that great floods were growing in height as well as in frequency.

The canals which were built at great expense during the first half of the last century were partly destroyed time and again by floods, and frequently recurring damage contributed in no small measure to cause their abandonment. Railroads have been relocating sections of line and raising tracks and bridges continually to keep above flood plain. The cities and towns, because of their rapid growth, however, have infringed more and more on the stream channels and, consequently, a considerable portion of the flood damage in recent years must be attributed to this cause.

The system of telegraphing the rise and fall of water was begun in 1872 and forecasting, in a small way, began in 1873. Forecasting by the U. S. Signal Service, the predecessor of the Weather Bureau in this service, began in Pennsylvania in about 1874 when six river stations in connection with the development of a flood warning

A paper presented on November 7, 1940, at the Four States Section Meeting, Wilmington, Del., by John W. Mangan, District Engineer, U. S. Geological Survey, Harrisburg, Pa.

service for Pittsburgh were established. This service was extended to the Susquehanna Basin in 1891 and to the Delaware Basin in 1903.

River and precipitation gages were established and became the working tools of the early forecasters. Studies were made to trace flood crests along the major tributaries and to develop stage relations. The few standard non-recording rain gages, while giving the forecaster some indication of general rainfall conditions, could, however, give little aid in interpreting anticipated run-off conditions.

Early Forecasting Techniques

It is well known that many factors are involved in the determination of the rate of flood travel and the estimation of expected flood heights. The condition of the soil; the extent and character of the snow cover, when present; the nature, distribution, and intensity of the rainfall are primary factors for consideration; and the conjunction of large tributaries along a parent stream often introduce problems of a perplexing nature. There is no doubt that the early forecaster, whose personal judgment played an all-important part in the prediction, did a very creditable job, considering the limited funds made available for this kind of work.

Flood forecasting along the lower reaches of the nation's larger rivers has offered no particular complications and the United States Weather Bureau has been performing this service properly for many years. The comparatively slow-moving crests in rivers such as the Mississippi, Missouri, and lower Ohio, have made it possible to issue warnings a sufficient time in advance of their arrival to allow for preparation and necessary evacuation. On the other hand, in Pennsylvania, where many of the cities and towns are located in the headwaters below relatively small drainage areas, the usual methods of forecasting which become operative after the flood peak has developed in the stream system, have not permitted sufficient time to issue proper warnings to the threatened areas.

The desirability of closely co-ordinating all meteorologic and hydrologic activities in Pennsylvania has been recognized for many years. The many difficulties involved in bringing Federal and state agencies together, however, seemed to prevent progress in this direction until the floods of March, 1936, brought the need for flood warning into prominence. Flood-warning service during this flood left much to be desired. Failure was caused partly by lack of proper knowledge for predicting major floods and partly by failure of telephone and telegraph communication systems.

Forecasting Survey in Pennsylvania

Early in 1937, the Pennsylvania Department of Forests and Waters, the United States Weather Bureau, and the United States Geological Survey, entered into a co-operative agreement, the purposes of which were to develop new and more adequate methods of river forecasting for Pennsylvania streams and to improve communication facilities to provide, if possible, more adequate forecasting service than was available at the time of the 1936 flood disaster.

As a first step in carrying out the terms of the agreement, a group of trained hydraulic engineers was organized for the studies.

Probably the greatest weakness at the time the investigations were initiated, in 1937, arose from the fact that the only recording precipitation records available for the study of past storms were those of the few first-order stations of the Weather Bureau. Heretofore, precipitation data were limited very largely to the records from standard gages which gave inadequate information about the distribution or intensity of rainfall. To improve this condition, approximately 100 recording rain gages were purchased and located to give proper state-wide coverage. At the same time, stream gaging activities were expanded to include many new discharge stations essential to the studies.

Adoption of Unit-Hydrograph Method

The procedure studied and finally adopted for use in flood forecasting in Pennsylvania is built around the unit-hydrograph method. This procedure was originated by L. K. Sherman in 1932, and elaborated upon by Merrill Bernard in 1934. The hypothesis upon which the method is based is that, in any drainage basin, surface runoff resulting from rainfall that is distributed with satisfactory uniformity, as to area and time, and that occurs in a given unit of time will produce hydrographs in which the bases are approximately equal and the ordinates vary with the magnitude of that portion of the rainfall which produces surface runoff. Thus, it is possible to treat a flood from a continuing rainfall through a process involving an integration of the unit-hydrograph.

Utilizing precipitation runoff relations for flood forecasting on so large a scale is relatively new. Where old methods took into account only the peak stage values, the unit graph affords a means for

dealing quantitatively with the rise and fall of a flood wave as modified by drainage basin characteristics.

The general plan for improving the forecasting service in Pennsylvania was directed towards an integrated forecast from headwaters to outlet. The individual basins were treated as units up to areas of a magnitude which preclude the application of average rainfall depths, after which the basin is treated as the composite of its watersheds. The computations for determining flood flow quantitatively are slow and laborious and considerable stress is placed upon the selection of small basins to serve as indices of probable runoff volumes for larger areas. The development of rainfall runoff relations permits a substantial interval between the time the forecasts can be inaugurated and the time when the flood peaks are reached and thus enables prediction with considerable accuracy of the anticipated runoff conditions before the complete runoff reaches the streams.

The recording precipitation stations, installed in Pennsylvania in 1937, have served little purpose in the current studies because of the short period of record. They will, however, become of considerable value in possible future revisions, in the light of the precipitation data now being collected. Also, the Weather Bureau has established, over the United States, nearly 1,000 additional recording rain gages which can be expected to add greatly to present knowledge of rainfall characteristics.

It would not be possible at this time to consider, further, the methods and procedures used in the Pennsylvania studies. Reference can be made, however, to a rather comprehensive report on the subject which is available to other states and agencies interested in this type of hydrologic work. The report, published as a special report of the Pennsylvania Department of Forests and Waters, is entitled, "Report of Co-operative Hydrologic Investigations in Pennsylvania," and was prepared by the three agencies co-operating in the study.

Organization of Forecasting Service

With the passage of state and Federal flood control acts and the beginning of construction of flood-control works, it was recognized, more than ever before, that an adequate flood-forecasting service in Pennsylvania was an integral part of any program for flood control, as reservoirs and dikes cannot be operated effectively unless such service is available.

Consequently, in order to pool their resources in this line of endeavor, to perfect a satisfactory system of forecasting which would not only handle the needs of flood control but also be of benefit to the public at large, the three organizations conducting the investigational work supplemented their original agreement to provide for this service in Pennsylvania. The new co-operative organization, known as the Federal-State Flood Forecasting Service, has offices at forecasting centers in Trenton, Harrisburg, and Pittsburgh. The work is handled under procedure set up by the supervising hydrologist of the United States Weather Bureau and is under the direct supervision of Weather Bureau officials at the forecasting centers.

The Federal-State Flood Forecasting Service has become the forerunner of advantageous co-operation between the Weather Bureau and other agencies. The nation-wide service conducted through 73 selected offices of the Weather Bureau is expanding to meet the special needs of the Corps of Engineers, the Tennessee Valley Authority, and the utility interests of the country. At the present time, forecasting procedures are being improved in all districts, based largely on the co-operative studies made in Pennsylvania.

Facilities for Communication

To make communication as fool-proof as possible in times of future emergency, the Pennsylvania Department of Forests and Waters has now installed an ultra-high frequency radio communication system for the entire Susquehanna River Basin, and this system will not only serve the needs of flood warning but of forest fire protection as well. The system is used daily for routine communication in bringing weather and stream flow observations to the forecast center at Harrisburg. It is expected that the system, which is entirely independent of telephonic communications or outside power, will be expanded, in the near future, to include the Ohio and Delaware Basins. In addition to this medium of communication, the Federal-State Flood Forecasting Service has the benefit of the meteorological data of the Weather Bureau transmitted at six-hour intervals by teletype from nearly 600 observation points over the United States.

The applications of stream flow records are many and varied. To the water works engineer, stream flow records are probably more

closely associated with studies relating to the design and operation of hydraulic works. The use of stream flow data in flood-forecasting procedure may be considered one of its relatively new and important uses. While the forecasting of floods is a Weather Bureau function, it is essential, because of the methods now employed, that the Weather Bureau and the Geological Survey work in close co-operation. Distributed throughout the United States, there are over 4,000 stream-flow gaging stations where accurate and continuous records of both river stage and discharge are obtained. These stations are operated by the Geological Survey in co-operation with 46 States through 46 district and sub-district offices. In Pennsylvania, 128 gaging stations are operated at the present time. While most of the Pennsylvania stations may be considered multiple-use stations, most of those located on the major tributaries are key stations in the flood-forecasting network, while many of the stations on smaller streams are index stations for definite areas. The gage structures, in many instances, are now used to house radio equipment which permits two-way radio communication between the gage and the forecasting center.

Great strides have been made in Pennsylvania, in the past few years, in hydrologic and meteorologic research, with every effort being made to bring flood-forecasting procedure to as high a degree of efficiency as possible. The large flood control program in Pennsylvania, part of which is already completed, enhances the immediate need for reliable flood-forecasting service. There is no doubt that funds expended on this work pay a very high return when the service rendered can prevent, even in a small measure, the property damage and personal suffering at times of flood disaster such as occurred in March, 1936.

Financing of Extensions in Los Angeles

By E. F. Dandridge

THE MEANS of financing water distribution system extensions are established as a part of the policy which is followed by the management in meeting all the financial requirements of a utility. It is therefore necessary to review, broadly, the general means which are open for financing all requirements in order to show what part the financing of extensions plays in the total financing picture.

The financial policy under which the utility operates should be established only after the management has determined what it must finance. This determination should be based upon studies which have seriously considered the probable future maintenance and operating costs; capital additions, betterments and replacements; debt service requirements; and any other items peculiar to the plant. It is not sufficient that such studies be made only at a time of financial emergency. The work must be recognized as a continuing necessity for the successful financial operation of the department. Facts must be faced squarely by both engineers and accountants. Inasmuch as the engineers are ordinarily responsible for the unusual, it is up to them to lay out, within reasonable limits, a long-term program designed to meet the probable expansion of the system. This should be in a constant state of revision as the passing of time indicates revision to be necessary. It is then necessary for the management to establish the extent to which the estimated annual capital outlay is to be paid from working capital, currently to be made available, and the amount which will be financed from borrowed funds, which in turn will create a debt which must be amortized over a period of years.

A paper presented on October 24, 1940, at the California Section Meeting, Los Angeles, by E. F. Dandridge, Chief Clerk, Bureau of Water Works & Supply, Los Angeles.

Sources of Income

In general, there are three ways—taxation, rates and contributions—which the municipality may follow in deriving its income; and the usual technique is some combination of at least two of these methods. Los Angeles, throughout its experience, has utilized all three to a considerable extent.

Taxation: During the early history of the Los Angeles Water Department, it was determined that it would be necessary to construct the Los Angeles Aqueduct to make available an adequate supply of water to meet the requirements caused by the rapid growth of the city. A large bond issue was voted; and for a period of time the debt service requirements on these bonds exceeded the total receipts of the Water Department. It was obvious that these bonds would have to be serviced by tax collections until such time as the revenues of the department were sufficient to take over the obligation. It seems that some such extraordinary condition must be evident before it is desirable to place any of the burden of the water system on the taxpayer.

Rates: Water rates should produce substantially all of the total annual requirements. In this respect it is impossible, usually, to keep away from years of peak requirements for construction work, so that it is essential in the growing system to utilize the department's authority to issue bonds, thereby maintaining rates at a uniform level over a period of years. Rates should be established at a level high enough to produce funds to pay for replacements of plant and system and a normal program of betterments and additions over and above that which is collected through contributions, in addition to maintenance and operation costs and annual debt service requirements.

Contributions: Under contributions are included receipts from consumers, the state, municipalities or other governmental agencies, and others, whether such contributions be in the form of cash, services or property. Such contributions may be in the aid of either maintenance or construction, although contributions in the aid of construction are by far the most common and are usually related to the installation of water mains, fire hydrants, service connections and meters.

There are a number of ways in which the department may receive these contributions, including: (1) grants from governmental agencies in connection with national work programs; (2) the formation of

districts under statutory authority, such as the Municipal Improvement District Act of 1915, and the Improvement Act of 1911 in California; (3) acreage supply charges; (4) service and meter installation charges; and (5) frontage charges and, working in conjunction with this, the frontage deposit which is refunded as the charge is collected upon the frontage covered by the deposit.

Frontage Charges

The general plan of financing extensions of mains of the Los Angeles Water Department is one of combining the use of frontage charges and revenues. The frontage charges are prescribed by rules and regulations governing water service which have been adopted by the Board of Commissioners. These rules fall under several classifications, as follows:

Extensions of Less Than 200 Ft.: Rule and Regulation No. 2 provides that a water main extension not exceeding 200 ft. from the existing main to the property requiring a water supply will be made upon payment of $.80 per front foot of the property to be served.

Extensions of More Than 200 Ft.: Rule and Regulation No. 3 provides that, where water main extensions exceeding 200 ft. in length are required, a deposit of $1.60 per lin.ft. shall be made. This deposit minus $.80 per front foot of the property frontage requiring service is to be refunded to payor or his assigns only if, as and when street frontage charges are collected from other consumers requiring service from the extension. The rule, however, may be waived by the chief engineer and general manager if a survey shows that such an extension will yield an income, from the sale of water alone, of at least 12½ per cent of the total investment in installing such extension in excess of 200 ft. Street intersections are not included in the measurement for extensions.

New Subdivisions (Residential): Before a subdivider can get the approval of the City Planning Commission for a new subdivision, the filing must be approved by the water department. To get this approval, the subdivider must make satisfactory arrangements with the water department for the installation of a complete water system, consisting of mains, service connections and fire hydrants. The department requires the payment of $1.60 per lin.ft. for piping of streets, in addition to the regular charge for fire hydrants and service connections. Prior to the time this was a requirement, the subdivider could have a tract piped by putting up a deposit of $1.60 per lin.ft., which was, then, refunded to him as frontage charges

were collected from the purchasers of the property. In this way, the subdivider could represent, at the time of selling the property, that the water was in the street, without explaining that before water could be connected to the property, a charge of $.80 per front foot, in addition to the service connection charge, would be required by the department.

Industrial Tracts: The charge of $1.60 per lin.ft. does not apply to the installation of water mains in industrial tracts. As a rule these installations require 8-inch and larger pipe to obtain a water supply that will be adequate at all times. These installations are charged for on a cost basis, including labor, material and appropriate overheads.

Retroactive Frontage Charges: In addition to the two rules mentioned above, there is a third rule under which the department collects frontage charges on property fronting water mains already installed. This is known as Rule and Regulation No. 1 and prescribes that owners of all property fronting on streets in which water mains have been laid since August 30, 1913, and who have not heretofore paid a frontage charge therefor, will be required to pay $.80 per front foot, in addition to the regular charge for the service connection, before water will be served. This same rule has been in effect since August 30, 1913, except that the rule at that time provided for a charge of $.40 per front foot, which amount was increased to $.80 in February, 1920.

Reduction of Revenue Requirements

Through the enforcement of these rules, the department hopes ultimately to collect a frontage charge for all water mains installed since 1913, although at the time of the financial requirement, substantially less than the installation obligation is likely to be collected. Over a period of years, however, it is found that collection of charges on property fronting mains already installed aids materially in reducing the requirement of revenues in the installation of new extensions.

The chief drain upon the revenues in this connection is not in the laying of pipe adequate to supply domestic, commercial and industrial demands, but in laying a size of pipe sufficiently large to meet the standards of the National Board of Fire Underwriters. It is a well established fact in the minds of most water works men that the investment in the water system which is necessary to meet the

accepted standards for fire protection is a very substantial amount of the total water works investment. It is also well established that most cities are not paid for fire hydrant service as such, but rather that the rates for other classes of service are raised to meet the burden occasioned by the necessity for this investment. This, combined with the fact that there is no contribution made toward the installation of the larger facilities necessary to supply adequate fire protection, creates a twofold problem.

In Los Angeles the record of payment of annual fire hydrant billings to the general fund of the city is very unsatisfactory. In this respect, it is substantially correct to say that the only bills which have been paid occurred at a time when it would have been necessary, because of the financial condition of the water department, to issue bonds requiring a vote of the people or to raise rates if such bills were not met. At these times, the city found it more expedient to pay the bills rather than to meet either of the other possibilities.

Each water department is faced with the problem of determining what may be a reasonable charge to the prospective consumer for extending a water main. This charge should be low enough to be within the means of the consumer, and still not impose an expenditure upon the water department which has no chance of justification economically. The average consumer requesting an extension is frequently confronted with financing construction of some sort and usually has arrived at the point of being committed to certain expenditures in that behalf without fully exploring the water supply situation. Very often the arrangement for water service offers the first contact between the department and a new consumer. The impression gained by the consumer at this time will be a lasting one, and it is important that it be favorable. The very fact that there is apt to be a charge of some kind to get the desired service places the department in the likely position of having to explain, to a person none too willing to listen, the reason for a charge. To do this satisfactorily is not easy.

There are some very good arguments against the practice of making a street main charge, but it is generally conceded that a charge of some kind is desirable. As long as the department is consistent, it seems reasonable to expect the consumer to pay an arbitrary frontage charge to offset the cost of pipe sufficiently large for an adequate domestic supply and to leave the balance, if any, as a current or deferred requirement of the revenue fund.

Application of the Hardy Cross Method to Distribution System Problems

By George Farnsworth, Jr. and August Rossano, Jr.

PROPER distribution of the public water supply depends primarily on the design of the distribution system and secondly on its operation. It has been estimated that from 50 to 70 per cent of the total cost of a water works may be allocated to the distribution system; yet, in spite of this fact, probably less attention has been given to its proper design than to that of any of the other physical equipment involved. This neglect is evidenced by the haphazard way in which new systems are laid out and in which reinforcing additions are made. Probably a very substantial saving in the cost of a water supply system could be effected with a more rational analysis of the system.

There exist at present three general scientific methods for the analysis of the flow in networks of pipe. These include: (a) the Freeman graphical method, modifications of which have been developed by Howland (1) and Aldrich (2); (b) the electrical network analyzer of Camp and Hazen (3); and (c) the Hardy Cross Method (4).

The Freeman graphical method involves so much labor in the solution of complex systems that it is not widely used. On the other hand, the equipment cost for the electrical analyzer method would seem to prohibit its wide adoption. The Hardy Cross method answers both these objections, permitting the solution of a complex network in a short time with the use of a pencil, paper, and a slide rule (5).

Application of the Hardy Cross method to the analysis of distribution systems indicates that pressure contours for towns of up to 15,000 population can be computed in a few hours. To demonstrate this

A contribution by George Farnsworth, Jr., and August Rossano, Jr., graduate students in civil engineering at the University of Illinois, Urbana, Ill.

fact, the authors undertook to analyze the distribution systems of Rantoul, Ill., (population, 2,000) and Ottawa, Ill., (population, 15,000). Since the method of analysis applied was the same for both distribution systems, only that of the larger will be described.

Outline of Distribution System

The Ottawa distribution system consisted of a network of 62 loops of pipes ranging in size from four to sixteen inches, covering an area of approximately four square miles. About three-quarters of the town is located in the valley of the Illinois River and the remaining quarter on the bluffs, at an elevation of 50 feet above the valley.

In the analysis, a fire was assumed to occur in a sanitarium located on the bluffs (Fig. 1). Two streams of 200 gallons per minute from each of three available hydrants were used to combat the fire. From a study of the consumption by the town on days of maximum demand, it was determined that the demand was 100 gal. per capita per day or 1,000 g.p.m. during the maximum hour. Thus the flows during the fire totaled 2,200 g.p.m.—fire demand, six streams at 200 g.p.m. or 54 per cent of the flow, and domestic demand, 1,000 g.p.m., or 46 per cent of the flow.

The domestic flow was distributed among one 9-per cent and two 3-per cent take-offs, representing the three largest industries (based on consumption figures), and thirty-one 1-per cent take-offs distributed throughout the town.

Procedure of Analysis

Formulas for the loss in head due to friction in a pipe line may be reduced to the form $h = rQ^n$; where h = loss in head in the pipe, Q = quantity of flow, r = the coefficient of resistance, which is determined by the size, length and roughness of the pipe, and n = an exponent varying according to the basic formula used. In the analysis, the Williams-Hazen formula was used.

In the design of distribution pipes, the value of C in the Williams-Hazen formula must be such that it reflects the condition of the pipe in the future. The same is true in problems of investigation of the adequacy of a distribution system already in operation. This value of C depends on the age of the pipe as well as on the quality of the water it is to carry, since some waters cause tuberculation and consequent rapid increase in frictional resistance. For the analysis made, the value of C was assumed to be 100 and the value of n, 1.85 throughout.

The following steps were taken in the analysis:

1. From the map of the town's water distribution system, the length and sizes of all pipes were determined (Fig. 1).

2. The value of r for each pipe was taken from the tables compiled by Doland (5) (Fig. 1).

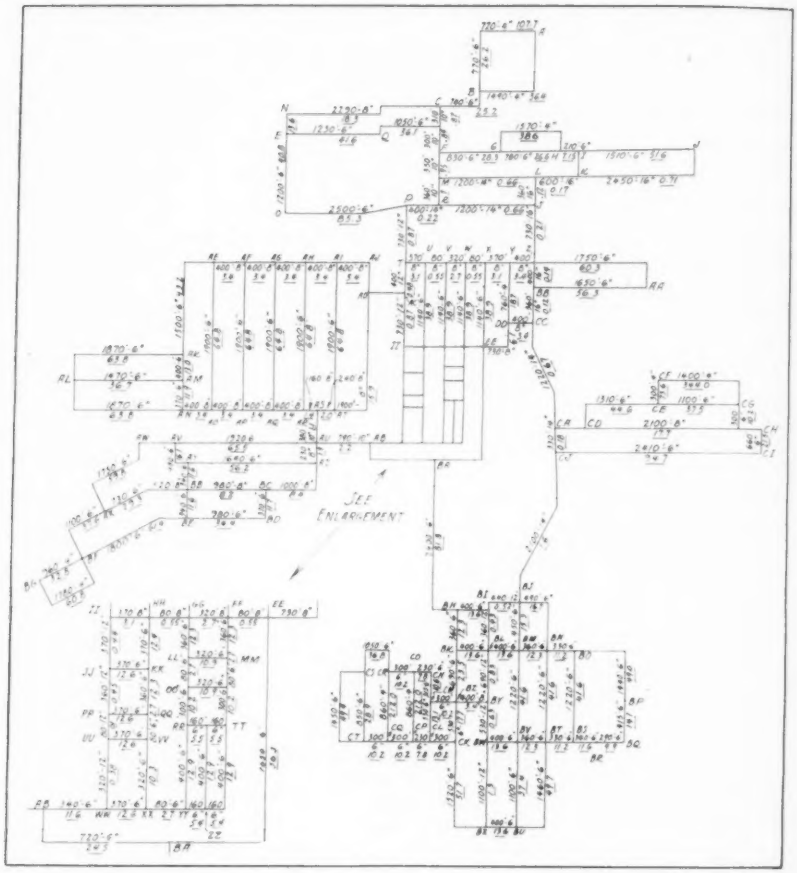

FIG. 1. Pipe Lengths, Sizes and Resistances at Ottawa, Ill. (resistances are underlined)

3. The take-offs were located in their respective positions and the flow in the system distributed (Fig. 2).

4. The analysis was computed by use of the Hardy Cross method.

5. Having determined the distribution of flow in each pipe (Fig. 2),

pressure contours were constructed. To do this, a pressure of 195 feet of water at the pumping station was used and the pressures throughout the system were calculated in reference to the pumping station level, using the computed losses of head in the pipes. These pressures were combined with the topographical elevations and the

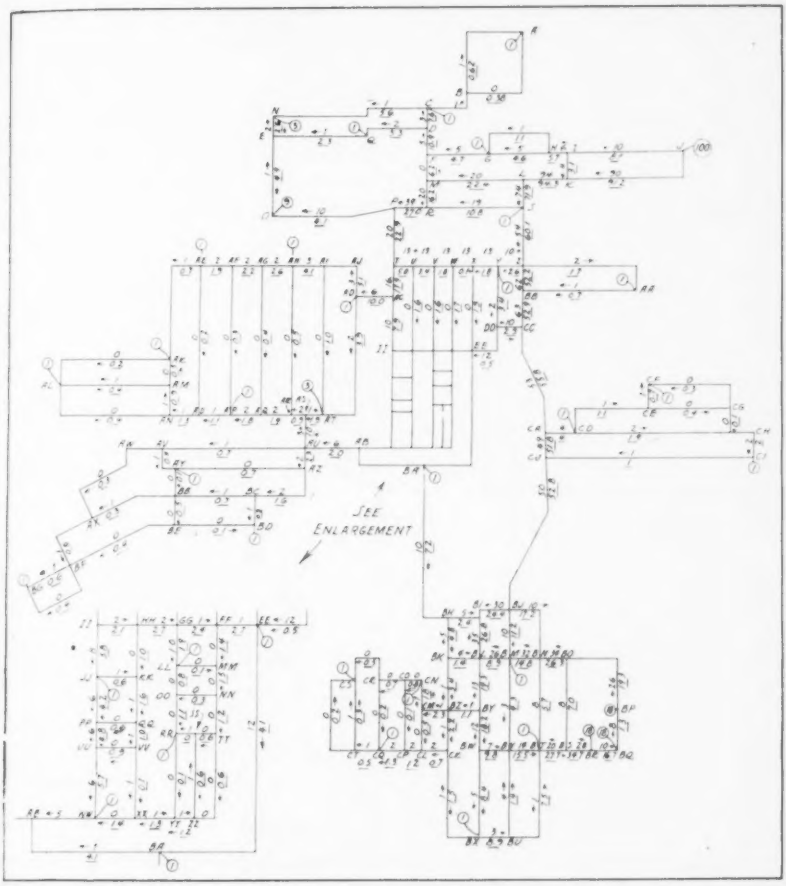

FIG. 2. Pipe Flows, Given as Per Cent of Total, at Ottawa, Ill.; showing computed flows (underlined) and assumed flows (not underlined)

actual contours computed. From these values, pressure contours were drawn (Fig. 3). To avoid confusion the piezometric elevations above the pumping station datum were not underlined, but the actual pressures were.

It may be observed from the results that a pressure of about 49 feet existed at the fire and that the pressures throughout the remainder of the system were adequate. This demonstrates that the distribution system, under the assumed conditions, was quite satisfactory.

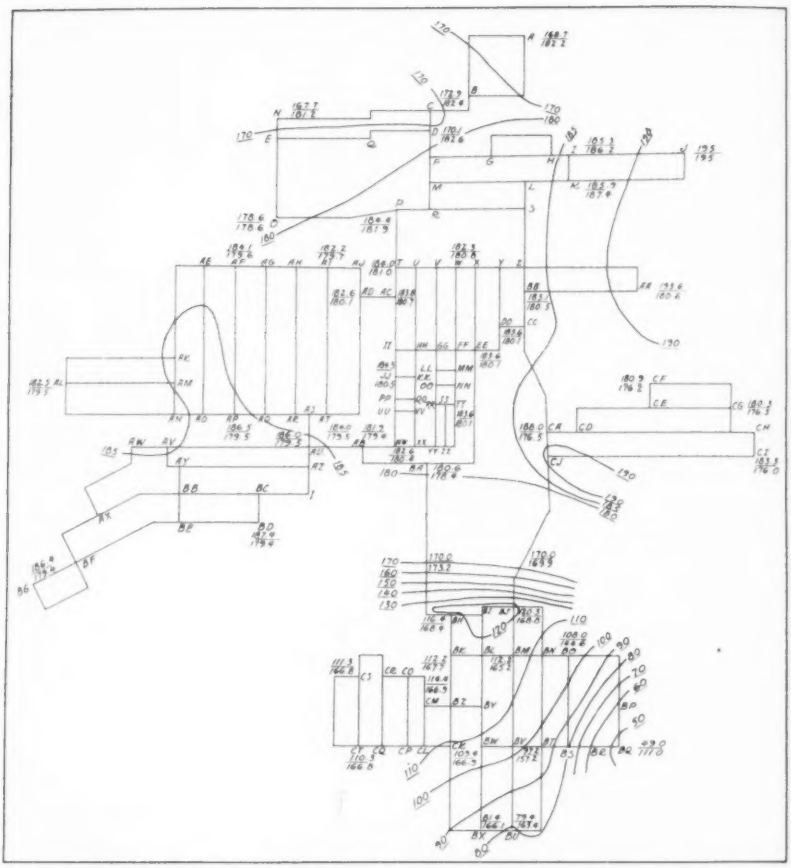

FIG. 3. Pressure Contours at Ottawa, Ill.; showing actual pressures (underlined) and piezometric pressures (not underlined) in feet of water

To illustrate the possibility of reducing the amount of work necessary to determine the pressure at the fire, an analysis was made of the system after the elimination of many of the pipes (Fig. 4). The same flows were assumed at the start of the analysis as were assumed in the first analysis.

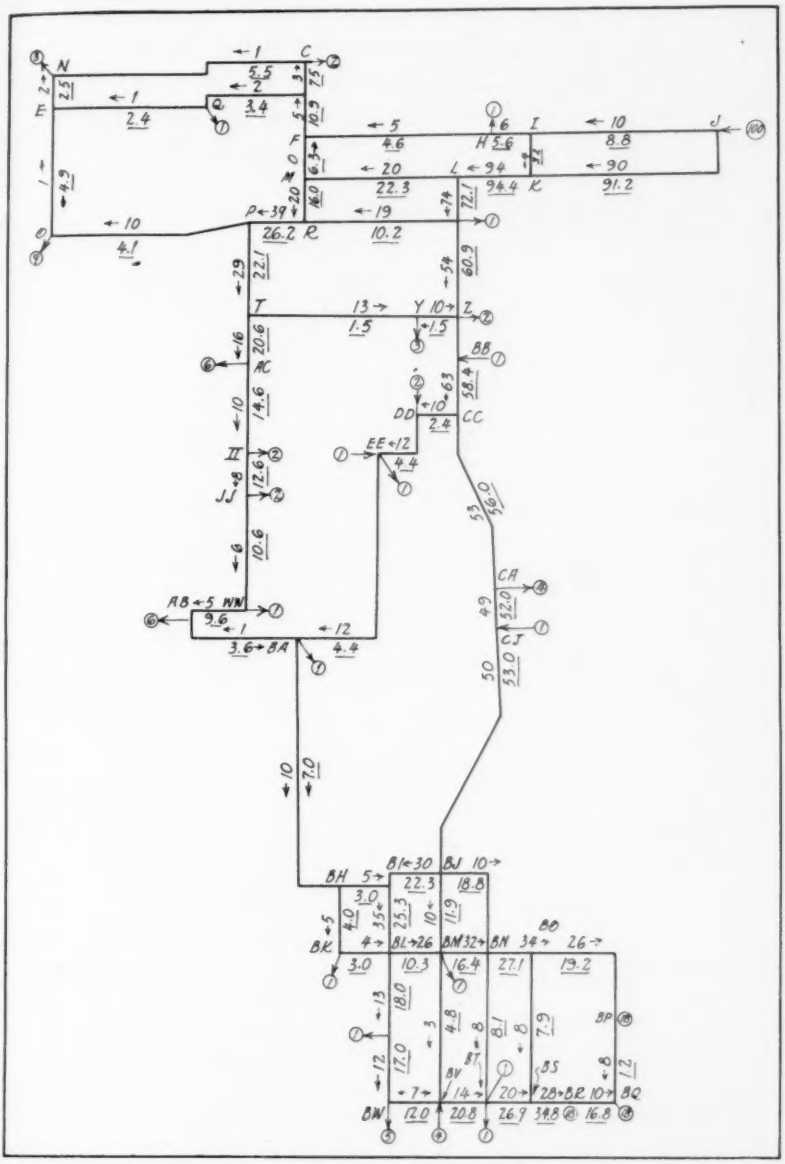

FIG. 4. Pipe Flows, Given as Per Cent of Total, Computed on a Simplified Network at Ottawa, Ill.; showing computed flows (underlined) and assumed flows (not underlined)

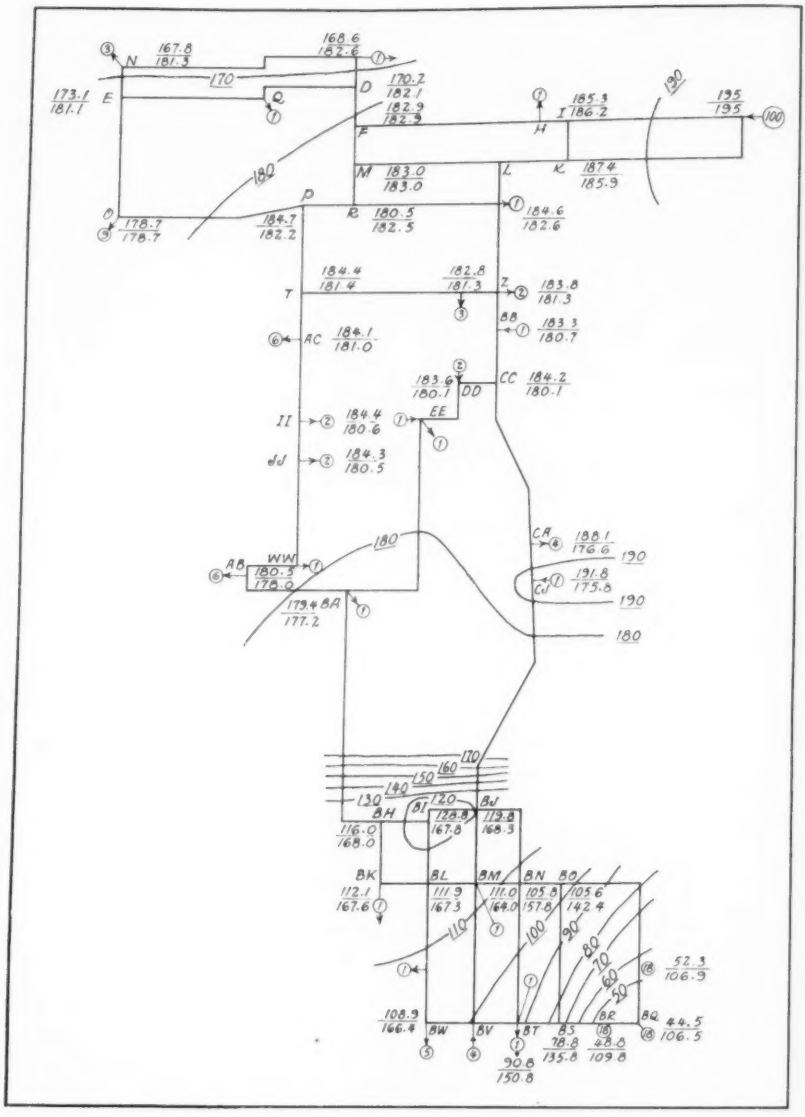

FIG. 5. Pressure Contours Computed on a Simplified Network at Ottawa, Ill., showing computed pressures (underlined) and piezometric pressures (not underlined) in feet of water

The pressure contours obtained in this simplified network are shown in Fig. 5. It will be noted that the pressures obtained in this case are about the same as those obtained in the first analysis.

Figure 6 shows the size, length, and resistance of all pipes, Fig. 7, the assumed and computed flows, and Fig. 8, the pressure contours for the Rantoul system. Since there is little difference in elevation throughout the town, the piezometric elevations above the pumping station datum coincide with the actual pressures.

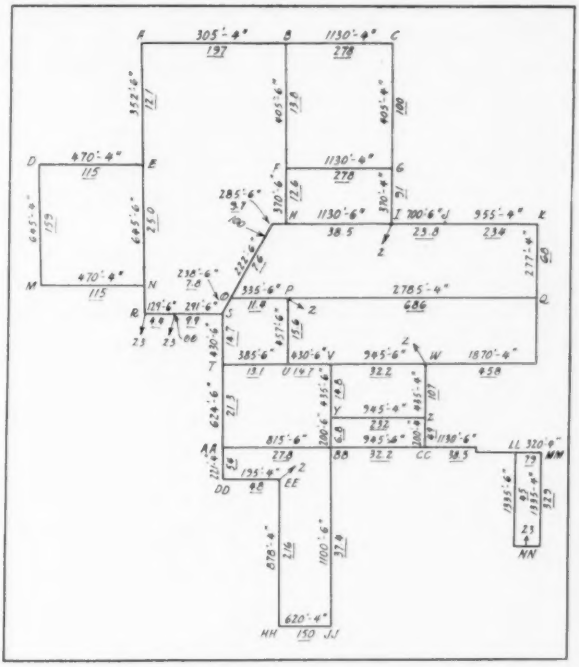

FIG. 6. Pipe Lengths, Sizes and Resistances at Rantoul, Ill. (resistances are underlined)

Conclusions

Approximately 30 man-hours were required for all the work necessary for the complete analysis of the Ottawa distribution system. Similarly, ten man-hours on the complete analysis of the simplified Ottawa network, and thirteen man-hours on the complete analysis of the Rantoul system were required. In the opinion of the authors, the time required for the analysis of a distribution system can be materially reduced with increased experience in the use of the Hardy Cross method.

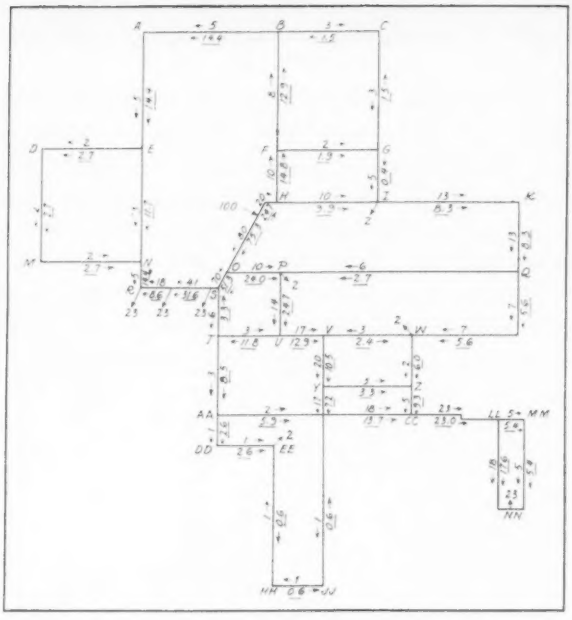

FIG. 7. Pipe Flows, Given as Per Cent of Total, at Rantoul, Ill.; showing computed flows (underlined) and assumed flows (not underlined)

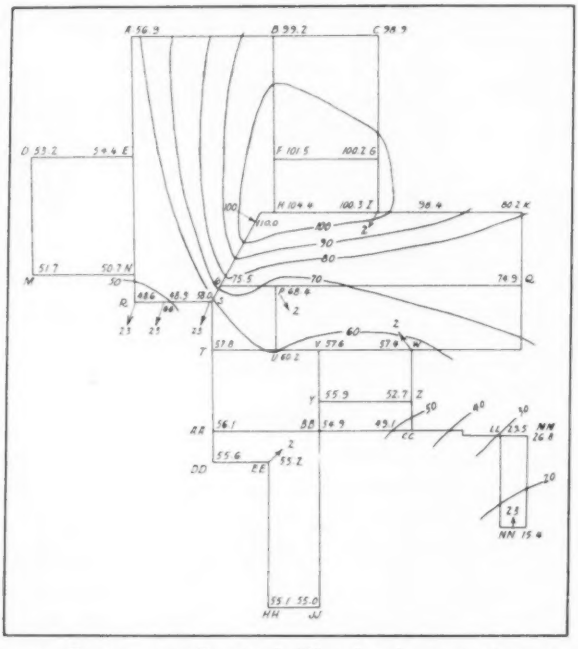

FIG. 8. Pressure Contours at Rantoul, Ill.; showing actual pressures in feet of water

It was found that five complete circuits in the distribution system were necessary to produce a maximum correction of 0.5 per cent in the final circuit. With this maximum correction, it was found that the maximum error in the computed head losses was less than 1 per cent. The maximum error in pressures seemed to come in loops of two parallel pipes where there were large flows with small resistances on one side and small flows with large resistances on the other. It was also found that any error made in the application of the flow corrections was automatically compensated in later corrections.

The Hardy Cross method seems to be applicable to all types of distribution systems, complicated or otherwise. In the hands of an experienced operator, the complexity of many systems can be reduced by the elimination of numerous pipes which have little bearing on the final pressures.

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Flow and Loss of Head in Distribution Systems

By J. J. Doland

SINCE the publication, in 1936, of the Hardy Cross method (1) for analyzing flow distribution, and since its application to water distribution systems by the writer (2), several modifications and variant applications have appeared in the literature of the field. In addition to these, consulting engineers have reported the practical use of the method in analyzing existing systems and in designing new ones. The writer has attempted to evaluate these contributions and to carry on further research with the idea of improving the methodology first proposed.

The results of the studies, thus far, have developed the following conclusions:

1. The use of percentage of total flow is superior to the use of flow in terms of gallons per minute.

2. The balancing of circuits can be accomplished more quickly and satisfactorily by the use of the exponent, 2 ($h = rQ^2$), instead of the exponent, 1.85 ($h = rQ^{1.85}$), because of the elimination of the need for special tables or exponential slide rule calculations for the balancing operations.

3. It is more practicable to plot pressure contours in terms of per cent of total available head, based on per cent of total flow, than in terms of feet of head for an assumed fixed demand in gallons per minute.

The advantages of the use of per cent of total flow rather than gallons per minute are twofold: (1) Once the circuits are balanced in terms of per cent, the indicated percentages may be applied to any total flow which may be carried by the system. (2) The use of percentages permits the use of smaller numbers for calculations than is possible by the use of gallons per minute. A practical solution

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A contribution by J. J. Doland, Professor of Civil Engineering, University of Illinois, Urbana, Ill.

rarely ever requires a balance closer than 0.5 per cent, and in most cases the actual calculations can be completed by the use of integers between 1 and 100.

The writer has tested the feasibility of using the relation $h = rQ^2$, in the balancing operations for a number of widely variable conditions, when the values of the different pipes in the circuit are determined from Table 1. The effect of this use of the exponent 2, instead of 1.85, is to show variations from the actual per cent of flow of from 0 to -2 per cent in that part of a circuit having the lesser resistance, and from 0 to $+2$ per cent in the part having the greater

TABLE 1

Values of r for 1,000 Feet of Pipe, Based on the Williams-Hazen Formula

(Head loss in feet $= r \times 10^{-5} \times Q^{1.85}$ per 1,000 ft., where Q represents flow in g.p.m.)

d	$C = 90$	$C = 100$	$C = 110$	$C = 120$	$C = 130$	$C = 140$
in.						
4	340	246	206	176	151	135
6	47.1	34.1	28.6	24.3	21.0	18.7
8	11.1	8.4	7.0	6.0	5.2	4.6
10	3.7	2.8	2.3	2.0	1.7	1.5
12	1.6	1.2	1.0	0.85	0.74	0.65
14	0.72	0.55	0.46	0.39	0.34	0.30
16	0.38	0.29	0.24	0.21	0.18	0.15
18	0.21	0.16	0.13	0.11	0.10	0.09
20	0.13	0.10	0.08	0.07	0.06	0.05
24	0.052	0.04	0.03	0.03	0.02	0.02
30	0.017	0.013	0.011	0.009	0.008	0.007

Example: r, for 12-inch pipe, 4,000 ft. long, where $C = 100$, is $1.2 \times 4.0 = 4.8$.

resistance. These calculations are based on circuits which carry proportionate parts of the entire 100 per cent flow such as 90–10, 70–30, etc. The error is reduced as the lower percentages of the total flow such as 30–20, 10–15–2–5, etc. are involved in any circuit.

After the balancing process is completed by the use of the exponent, 2, calculations for loss of head and the position of contours should be made by using the relation $h = rQ^{1.85}$. The head loss discrepancies may then be adjusted in the usual way.

After the percentage of flow carried by each line has been determined for any assumed condition of supply and demand, the relative loss of head between any two points in the system can be

calculated by summation of the h values ($h = rQ^{1.85}$) for each pipe which forms a part of the path from one point to the other. The maximum value of Σh will indicate the maximum loss of head which can occur under the assumed conditions and, hence, will determine the point at which the lowest pressure will occur. Points at which convenient percentages of this maximum value occur may then be plotted and contour lines drawn through them. This method of illustrating the operation of a given system is a convenient way of illustrating the pressure conditions which prevail in all parts of the system. The use of percentages of flow and percentage loss of head has the advantage of being applicable to any flow in gallons per minute which may be assumed as the total flow in the system through the use of the conversion formula:

$$h\,(\text{ft.}) = \frac{\Sigma h}{100{,}000}\,(0.01\ \text{g.p.m.})^{1.85}$$

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Computation of Equivalent Lengths of Parallel Pipe Systems

By W. E. Howland and F. Farr, Jr.

ONE pipe may be said to be equivalent to another or to a system of others when it can carry the same total flows at the same overall head losses.

The ratio of flows in any two pipes according to the Williams-Hazen equation is given by the following:

$$Q_0/Q_1 = C_0/C_1\ (D_0/D_1)^{2.63}\ (h_0/h_1)^{.54}\ (L_1/L_0)^{.54} \quad \ldots\ldots\ldots (1)$$

where Q is the flow, C, the coefficient in the Williams-Hazen equation —often given as $v = C\left(\frac{D}{4}\right)^{.63}\left(\frac{h}{L}\right)^{.54}\ 0.001^{-\ 0.04}$—$D$ is the diameter, h is the head loss, and L, the length of the pipe; and the subscripts (0) and (1) indicate the particular pipe to which the quantity belongs or in which it occurs.

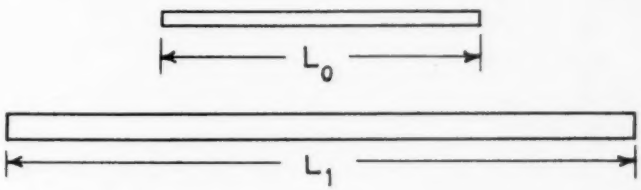


FIG. 1. EQUIVALENT PIPES

From Equation (1) it follows that two single pipes say "0" and "1" as shown in Fig. 1 will be equivalent to each other when the following equation is satisfied:

$$L_1 = (D_1/D_0)^{4.87}\ (C_1/C_0)^{1.85}\ L_0 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

A contribution by W. E. Howland, Associate Professor of Sanitary Engineering, and F. Farr, Jr., Instructor in Civil Engineering, of Purdue University, Lafayette, Ind.

TABLE 1

Equivalent Lengths of Pipes of Various Sizes Having Same Loss of Head as One Foot of Smaller Size

$$\left(\left(\frac{D_1}{D_0}\right)^{4.8704}\right)$$

D_0											D_1
4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.	22 in.	24 in.	30 in.	in.
1.000												4
7.205	1.000											6
29.25	4.060	1.000										8
86.72	12.04	2.965	1.000									10
210.7	29.25	7.205	2.430	1.000								12
446.5	61.97	15.26	5.149	2.119	1.000							14
855.6	118.7	29.25	9.866	4.060	1.916	1.000						16
1518.	210.7	51.91	17.51	7.205	3.401	1.775	1.000					18
2537.	352.1	86.72	29.25	12.04	5.681	2.965	1.671	1.000				20
4035.	560.0	137.9	46.53	19.15	9.037	4.716	2.657	1.591	1.000			22
6164.	855.6	210.7	71.08	29.25	13.81	7.205	4.060	2.430	1.528	1.000		24
	2537.	624.8	210.7	86.72	40.93	21.36	12.04	7.205	4.529	2.965	1.000	30
	6164.	1518.	512.2	210.7	99.47	51.91	29.25	17.51	11.01	7.205	2.430	36

Table 1 shows values of $(D_1/D_0)^{4.87}$ for a great many ratios (D_1/D_0) of standard pipe diameters. Since C_1/C_0 is often equal to unity, Table 1 makes the calculation of L_1 a very simple operation.

When two pipes are connected in parallel, as shown in Fig. 2, and when there are no intermediate take-offs the same head loss occurs in each and the ratio of the flows in one of them, pipe "0," to the flow in the other, pipe "2," is given by the following equation which follows from the principle expressed in Equation (1),

$$Q_0/Q_2 = C_0/C_2\ (D_0/D_2)^{2.63}\ (L_2/L_0)^{.54} \quad \ldots\ldots\ldots\ldots (3)$$

But pipe "0," for purposes of convenience in analysis, may be replaced by an equivalent pipe whose diameter and coefficient are

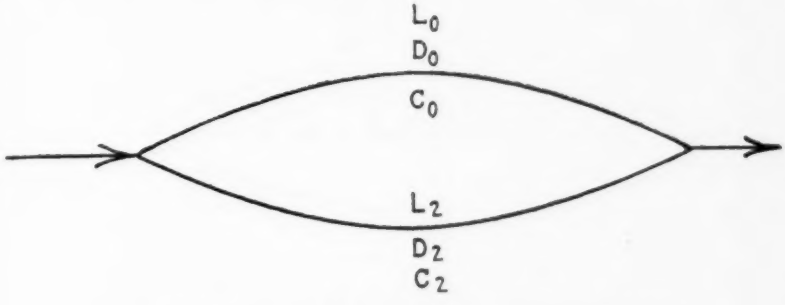


FIG. 2. FUNCTIONALLY PARALLEL PIPES

the same as those of pipe "2"; *i.e.*, $D_1 = D_2$ and $C_1 = C_2$. The relation between L_0 and its equivalent length L_1 is given by Equation (2). Then in place of Equation (3) one may write:

$$Q_0/Q_2 \text{ or } Q_1/Q_2 = (L_2/L_1)^{.54} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

A single pipe L_x in length may now be found which is equivalent to the functionally parallel pipes shown in Fig. 3. Such a pipe will be able to carry a flow Q_x equal to $Q_1 + Q_2$ at a head loss h_x equal to h_1 which is also equal to h_2. Thus,

$$Q_x/Q_2 = \frac{Q_1 + Q_2}{Q_2} = Q_1/Q_2 + 1 = (L_2/L_x)^{.54} \quad \ldots\ldots (5)$$

This equation results from the application of the principle expressed in Equation (1). Replacing, in Equation (5), Q_1/Q_2 by $(L_2/L_1)^{.54}$ from Equation (4), Equation (5) becomes,

$$L_x/L_2 = \left[\frac{1}{1 + (L_2/L_1)^{.54}}\right]^{.54} \quad \ldots\ldots\ldots\ldots \quad (6)$$

Relations between L_x/L_2 and L_2/L_1 for all values of L_2/L_1 less than unity may be read directly with a high degree of precision from Fig. 4. Thus, in using this chart, it is convenient to define L_2 as the smaller of the two functionally parallel pipes. L_x, then, is always equal to the ratio L_x/L_2 (read from the left side of the graduated lines on the chart) times the smaller of the two original pipes L_2.

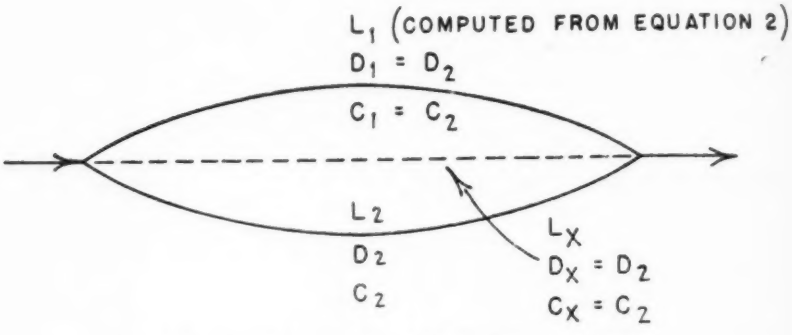


FIG. 3. FUNCTIONALLY PARALLEL PIPES (EQUIVALENT TO FIG. 2)

The use of the chart can best be illustrated by means of examples. The first is a simple example; the second is more complex.

Example 1

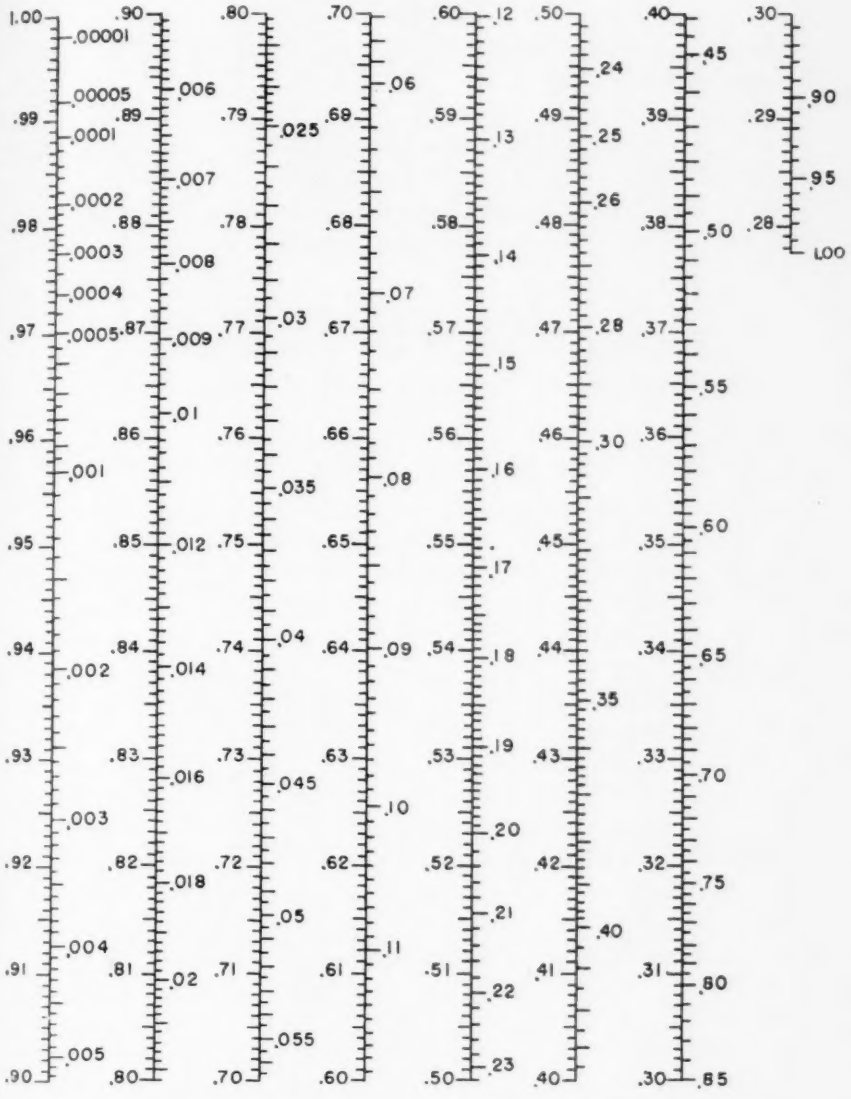
What length of 12-inch pipe is equivalent to a pair of parallel pipes of equal roughness, one a 10-inch pipe, 1,500 ft. long and the other a 12-inch pipe 1,000 ft. long?

Solution:

The 10-inch pipe is equivalent to 1,500 × 2.430 (from Table 1) = 3,645 ft. of 12-inch pipe. Call this L_1.

$L_2/L_1 = 1{,}000/3{,}645 = 0.274$; $L_x/L_2 = 0.474$ (from Fig. 4).

Then $L_x = 0.474 \times 1{,}000 = 474$ ft. of 12-inch pipe (same roughness as original pipes).



L_x/L_2 PLOTTED ON THE LEFT. L_2/L_1 PLOTTED ON THE RIGHT.

FIG. 4. CHART FOR DETERMINATION OF EQUIVALENT LENGTHS OF PARALLEL PIPES.

Example 2

Find the equivalent length in 8-inch pipe, $C = 100$, of the pipe network shown in Fig. 5.

Method:

Find the equivalent length of the loop BD in 8-inch and add to AB and to DFG to get the equivalent length of the line $ABDFG$.

Find the equivalent length of the loop KN in 8-inch and add to AJK and to NG to get the equivalent length of the line $AJKNG$.

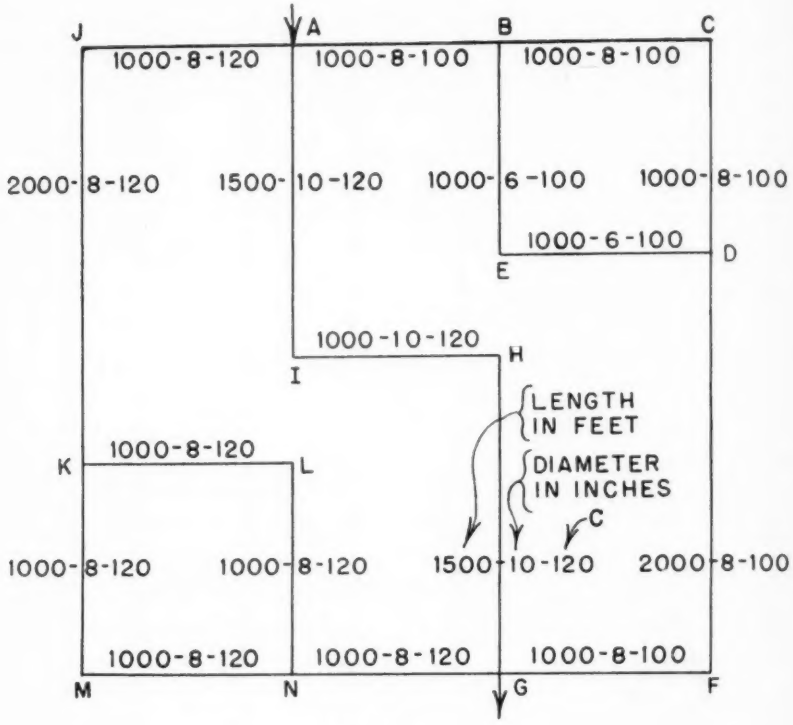


FIG. 5

Find the equivalent length AG_1, of $AJKNG$ and of $AIHG$ (change first to 8-inch) and change to length of $C = 100$; then find the equivalent length of this and of $ABDFG$ which is the answer AG.

Solution:

BED in 8-inch pipe = 2,000 × 4.060 (from Table 1) = 8,120 ft.

BCD/BED = 2,000/8,120 = 0.246; (from Fig. 4) BD/BCD = 0.491.

$BD = 0.491 \times 2{,}000 = 982$ ft. of 8-inch

$ABDFG = 982 + 4{,}000 = 4{,}982$ ft. of 8-inch, $C = 100$

$KLN/KMN = 2{,}000/2{,}000 = 1.0$; (from Fig. 4) $KN/KMN = 0.2775$

$KN = 0.2775 \times 2{,}000 = 555$ ft. of 8-inch

$AJKNG = 555 + 4{,}000 = 4{,}555$ ft. of 8-inch, $C = 120$

$AIHG$ in 8-inch $= 4{,}000/2.965$ (from Table 1) $= 1{,}350$ ft., $C = 120$

$AIHG/AJKNG = 1{,}350/4{,}555 = 0.296$; (from Fig. 4) $AG_1/AIHG = 0.462$

$AG_1 = 0.462 \times 1{,}350 = 624$ ft. of 8-inch, $C = 120$

AG_1 for $C = 100$, $624 \times (100/120)^{1.85} = 446$ ft. of 8-inch

$AG_1/ABDFG = 446/4{,}982 = 0.0895$; (from Fig. 4) $AG/AG_1 = 0.641$

$AG = 0.641 \times 446 = 286$ ft. of 8-inch, $C = 100$ (answer).

Tables 2 and 3 are included as illustrations of the application of the above methods and because of the intrinsic value of the information which they contain. These are of practical use when a pipe is to be laid parallel to an existing line for a portion of its length to satisfy an immediate demand for increase in capacity (or a decrease in head loss) with a view toward ultimate complete extension of the new line to meet the anticipated greater future demands. Values in the body of Table 2 represent the percentage decreases, in the head losses along a pipe line, which may be expected as pipes of various sizes (indicated by the values at the bottom of the table) are laid parallel to the original pipe along various percentages of its length. Values in the body of Table 3 represent the percentages of the length of the original line which must be paralleled by another pipe (of size indicated at the bottom of the table) in order to increase the capacity of the entire system by the percentages indicated at the left of the table.

The values in these tables are applicable not only to the pipes whose sizes are indicated at the bottom of the tables, but also to other sizes of pipes whose ratios of diameters are the same. Thus, the values in column one of these tables are applicable not only to the pair of pipes shown, 4-inch and 6-inch, but also to 8-inch and 12-inch, 12-inch and 18-inch, or to any other pair of pipes having this two to three ratio of diameters.

The concept of equivalent lengths as used in this paper has not been extended to include any pipe system in which there are inter-

mediate take-offs, although it could be applied to a portion of such a system between which there are no intermediate take-offs.

TABLE 2

Decrease in Required Head Loss to Discharge a Constant Flow as Various Lengths of a Parallel Pipe of Various Sizes Are Added

PER CENT OF LENGTH ADDED	DECREASE IN HEAD LOSS IN PER CENT OF ORIGINAL HEAD LOSS									
100	92	88	85	83	72	59	56	51	42	24
90	83	79	77	75	65	53	50	46	38	22
80	74	70	68	67	58	47	45	41	34	19
70	64	62	60	58	51	41	39	36	30	17
60	55	53	51	50	43	35	34	31	25	15
50	46	44	43	42	36	29	28	25	21	12
40	37	35	34	33	29	24	22	20	17	10
30	28	26	26	25	22	18	17	15	13	7
20	18	18	17	17	14	12	11	10	8	5
10	9	9	9	8	7	6	6	5	4	2
Original Pipe, *in.*..	4	6	8	10	12	12	10	8	6	4
Added Pipe, *in.*....	6	8	10	12	12	10	8	6	4	2

TABLE 3

Lengths of Parallel Pipe of Various Diameters Required to Increase Flow by Various Percentages, Head Loss Remaining Constant

PER CENT INCREASE IN FLOW	LENGTH REQUIRED IN PER CENT OF ORIGINAL PIPE									
100	79	82	85	87	100					
90	76	79	82	84	96					
80	72	75	78	80	92					
70	68	71	74	75	87					
60	63	66	68	70	80	99				
50	58	60	62	64	73	90	95			
40	50	53	55	56	64	79	83	91		
30	42	44	45	46	53	65	69	76	91	
20	31	33	34	34	40	49	51	56	68	
10	18	18	19	19	22	27	29	32	38	67
Original Pipe, *in.*...	4	6	8	10	12	12	10	8	6	4
Added Pipe, *in.*....	6	8	10	12	12	10	8	6	4	2

Furthermore, the method of computing the equivalent length of a parallel pipe system as described herein fails when there is a con-

necting pipe extending between an intermediate point on one of a pair of functionally parallel pipes to an intermediate point on the other of the pair. This is called a cross-over (Fig. 6).

To find the head loss from *a* to *b* in Fig. 6 other methods must be employed, as for example the geometrical method of one of the authors,* the Hardy Cross method† or other cut and try methods; but when the head loss for a given flow has been found, the equivalent pipe may be used to replace this system in subsequent computations of which the system is a part.

Although the method described in this paper is not strictly applicable to complicated interconnected grid systems, it may be used with exactness to simplify certain portions of those networks. Also it may be used to advantage to obtain approximate solutions

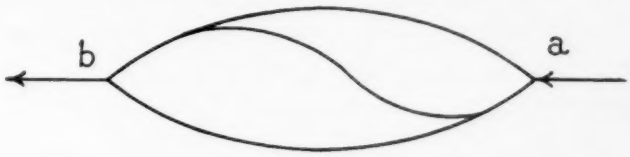


FIG. 6. CROSS-OVER

for some complicated networks after they have been arbitrarily simplified by the omission of cross-over pipes and minor take-offs.

The authors are indebted for the basic algebra and the concept of equivalent pipes and for Table 1 to Professor R. B. Wiley, Head of the School of Civil Engineering at Purdue University, who, in turn, believes that he is indebted to E. S. Rankin, formerly of Pearse, Greeley, and Hansen, Sanitary Engineers, for these ideas. They are also indebted to R. C. Wagner, former Purdue student, for help in constructing Fig. 4.

* HOWLAND, W. E. Expansion of the Freeman Method for the Solution of Pipe Flow Problems. J.N.E.W.W.A., **48:** 408 (1934).

† CROSS, HARDY. Analysis of Flow in Networks of Conduits or Conductors. Eng. Expt. Station, Univ. of Illinois, Bul. No. 286 (Nov. 13, 1936); FAIR, G. M. Analyzing Flow in Pipe Networks. Eng. News-Rec., **120:** 342 (1938).

A Rapid Method for the Determination of Zinc in Water Supplies

By Merrill L. Riehl

ALTHOUGH many methods for the quantitative determination of zinc are given in the literature, most of them are unsatisfactory in one way or another. While employed at the Columbus, Ohio, water softening and purification plant, the author adopted the following method, which is based on two brief paragraphs in the *Analyst* (1, 2).

Scope

1. The method involves the determination of relatively small amounts of zinc in water supplies by the precipitation of the zinc ion with sodium diethyldithiocarbamate, comparing the resultant turbidity with standard solutions containing known amounts of zinc. Directions for the preliminary treatment of both the sample and standards are given.

Application

2. In the absence of lead, copper, or relatively large amounts of iron, the zinc content may be easily determined by this method. Lead ions also cause a turbidity with the reagent, thus interfering. The presence of copper ions creates a yellow-colored solution, which may be removed by extraction. Iron is normally found in concentrations too low to cause interference.

Solutions Required

3. (*a*) *Sodium diethyldithiocarbamate, 0.1 per cent solution.* Dissolve 0.1 gram in 100 ml. distilled water. A fresh solution should be made up at frequent intervals and should be stored in the dark.

A contribution by Merrill L. Riehl, Instructor in Chemical Engineering, Case School of Applied Science, Cleveland, Ohio.

(*b*) *Diluted sulfuric acid, N/50.*

(*c*) *Diluted sulfuric acid, N/5.* (For highly alkaline samples, a more concentrated acid should be used to maintain the volume of the sample as close to 100 ml. as possible.)

(*d*) *Standard zinc solution, 0.1 mg. per ml.* Dissolve 0.1 gram of pure zinc metal in a slight excess of HCl and dilute to 1 liter with distilled water.

(*e*) *Zinc-free water* (*optional*). Water having a mineral content similar to that of the sample, but free of zinc.

(*f*) *Carbon tetrachloride.* This is needed only when copper is present in amounts sufficient to cause a yellow color.

Procedure

4. *Volume of sample.* (*a*) If the zinc content of the sample is less than 5 p.p.m., 100 ml. of the sample should be used.

(*b*) For water containing more than 5 p.p.m. zinc, a correspondingly smaller amount of sample should be used, bringing the volume up to 100 ml. with either distilled water or zinc-free water.

5. *Determination of alkalinity of sample.* The total alkalinity of the sample, to methyl orange indicator, should be determined, titrating with $N/50$ H_2SO_4. This should be determined on a separate portion of the sample and after dilution in the case of high zinc concentration.

6. *Neutralization of the sample.* Add 100 ml. of the sample, after dilution in the case of high zinc concentration, to a 100-ml. Nessler tube. To this add the required amount of $N/5$ H_2SO_4 to neutralize the alkalinity as determined in Section 5. Mix by inverting several times. (If the sample is highly alkaline, it should be neutralized by a more concentrated solution of acid, to keep the volume down.)

7. *Development of turbidity.* Add 2 ml. of the 0.1 per cent solution of sodium diethyldithiocarbamate to the sample in the Nessler tube. Mix by inverting several times.

8. *Removal of copper coloration.* If a yellow-colored solution, due to copper, results on addition of the carbamate, transfer the sample to a 250-ml. separatory funnel and extract with 2-ml. portions of CCl_4 until the final CCl_4 portion is colorless. Discard the CCl_4 portions and transfer the sample back to the Nessler tube.

9. *Time of standing.* The samples should be allowed to stand at least 5 min. and not over 15 min. after the addition of the carbamate reagent, before comparing with the standards.

10. *Preparation of Standards.* (*a*) To matched Nessler tubes add standard zinc solution in the range needed, but in no case should more than 5 ml. be used. Fill to the 100-ml. mark with either distilled water or zinc-free water. Mix by inverting. (Distilled water is usually satisfactory, but more accurate results may be obtained by using zinc-free water.) (If zinc-free water is used, its alkalinity should be determined, as in Section 5, and the alkalinity neutralized before adding the water to the Nessler tubes containing the standards.)

(*b*) To each tube add 2 ml. of the sodium diethyldithiocarbamate solution. Mix by inverting.

(*c*) Allow to stand for 5 to 15 min. before comparing. (It is desirable to carry the preparation of both the sample and standards to the point of addition of the carbamate solution, then add the carbamate to all the tubes at the same time.)

11. *Comparison of sample and standards.* By careful selection of a dark background, and by viewing the tubes lengthwise, the turbidity may be differentiated in intervals of 0.1 to 0.2 p.p.m. zinc, especially in the lower range from 0.1 to 1.5 p.p.m. For less exact work, or for from 0.15 to 0.5 mg. of zinc (1.5 to 5.0 ml. standard zinc solution) 0.3 to 0.5 p.p.m. intervals may easily and rapidly be detected.

12. *Calculation.* If 100 ml. of sample were used, the zinc content, in parts per million, is numerically equal to the number of milliliters of standard zinc solution in the tube most nearly comparing to the turbidity of the sample. If the sample was diluted, the results may be calculated thus:

$$\text{Zn (in p.p.m.)} = \frac{100}{\text{volume of sample (in ml.)}} \times \text{standard (in ml.)}$$

References

1. Callan, Thomas and Henderson, J. A., Russell. A New Reagent for the Colorimetric Determination of Minute Amounts of Copper. Analyst, **54:** 650 (1929).

2. Atkins, W. R. G. The Determination of Zinc in Water by Means of Sodium Diethyldithiocarbamate. Analyst, **60:** 400 (1935).

Super-Chlorination and De-Chlorination

By Marsden C. Smith and Howard E. Lordley

IT IS indeed strange that so many operators fail to appreciate the vast increase in plant efficiency and the reduction in operating problems which result from a conscientious and thorough study of the all-important problem of preparing a water for filtration. A contrast of the condition of the Richmond filters some years ago—full of mud balls and cracks—with that since preparation methods have been perfected is adequate to convince anyone of the value of this phase of plant operation. With present methods, a clean, sharp sand is maintained with no attention but the standard washing at from 100- to 300-hour intervals; and the improvement in the quality of the finished water is striking. Finding the best chemical and mechanical preparatory treatments for any particular water is not always an easy task, but once the proper method is found, the plant is assured that its filters will bear a minimum burden of purification, acting, for the most part, as mere strainers and polishers of the supply.

Before proceeding with a discussion of the various types of treatment used in preparing a water for filtration, it will be well, here, to define several of the terms as they are used in this article.

Pre-chlorination means applying chlorine before coagulation.

Super-chlorination means such a heavy pre-chlorination that a controllable method of reducing the residual becomes necessary.

De-chlorination means the addition of some chemical or treatment for the purpose of reducing the chlorine residual to a desired value.

Break-point chlorination means using that amount of chlorine which just satisfies the chlorine demand of the water. Some prefer

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A paper presented on September 6, 1940, at the Virginia Section Meeting, Charlottesville, Va., by Marsden C. Smith, Chief Engineer, Department of Public Utilities, Richmond, Va., and Howard E. Lordley, Plant Manager, Filtration Plant, Richmond, Va.

to define super-chlorination as chlorination in excess of the break-point.

Without doubt, super-chlorination is one of the most important chemical treatments in modern plant operation. It should be realized, however, that the subject is not a new one. Norman J. Howard used super-chlorination and de-chlorination successfully at Toronto for many years. The break-point chlorination, of which so much has recently been written, is really new only in name. In 1936, one of the authors reported the striking reduction in taste and odors obtained when pre-chlorination doses were kept *above* certain amounts (1)—an early use of the "break-point" idea.

Benefits of Pre-Chlorination

At the suggestion of Linn H. Enslow, pre-chlorination was first used at Richmond to aid coagulation. Organic matter in a raw water always tends to inhibit coagulation and any water having a high organic content is more than apt to be difficult to prepare for filtration. Chlorine strongly affects the composition of most such organic compounds, reducing or eliminating their coagulation-inhibiting ability; so, inasmuch as most filter plants must use a raw water of some organic content, pre-chlorination is far more than likely to prove helpful in coagulation. Whether or not we realize such to be the case, coagulation is the most important phase of rapid sand filtration.

Because sterilization is the one *must* of any water purification operation, there is another, and possibly more important, need for pre-chlorination. Health authorities have recently been much perplexed by unexplained outbreaks of gastro-enteritis and other gastric disturbances. Fairly or unfairly, this has cast suspicion upon the effectiveness of sterilization by chlorination as practiced in many water purification plants. Short time contact in limited quantities of chlorine concentration is certainly neither a reliable nor an unfailing germicide. On the other hand, even the most skeptical health official feels full confidence in the certainty of complete sterilization when there is a long retention of the treated water in a high chlorine concentration.

There are other real benefits to be derived from pre-chlorination, one of which is that pre-chlorination satisfies the chlorine demand of the raw water before filtration. By this means, the residual in the water reaching the consumer may be much more exactly controlled.

In addition, the satisfaction of the chlorine demand produces a more persistent chlorine residual in the distribution system; hence, it is a tremendous aid in reducing "dead-end" depreciation of water quality.

Still another benefit of adequate pre-chlorination is the prevention of decomposition of the sludge in the settling basins, so common in warmer climates. It is expensive to empty and scour settling basins and, no doubt, the reduction in the number of necessary cleanings of these basins at Richmond creates savings equivalent to the entire cost of pre-chlorination.

Pre-Chlorination Problems

Unfortunately, new problems are often created by the effort to use large quantities of chlorine before filtration. An intolerable increase in taste and odors may be the result of increasing the quantity of chlorine used. Another problem is the rapid dissipation of chlorine in water exposed to sunlight. If sufficient chlorine is added to the raw water to provide for this loss from sunlight, an excessive quantity of chlorine will reach the filters whenever clouds obscure the sun. Yet, if smaller quantities are added and the chlorine demand of the water, aided by a bright sun, leaves no trace of chlorine at the filters, who can prove the efficiency of sterilization? Quite naturally investigators directed their attention to the elimination of these problems. From such study, activated carbon and break-point chlorination have been developed to solve the problem of chlorinous tastes produced by pre-chlorination; and now de-chlorination is urged as a solution to the problem of the maintenance of a fixed chlorine residual when correct pre-chlorination is used. Therefore, since we must agree that pre-chlorination is almost essential, and since so much has been written about activated carbon, a description of break-point and de-chlorination is necessary to an understanding of the situation.

Break-Point Chlorination

The splendid work on break-point chlorination which has recently been done by many investigators furnishes a means to reduce to a minimum the work required to determine the most efficient pre-chlorination treatment for any plant. Particular attention is called to the excellent bulletin on the laboratory method for the study of super-chlorination issued by the Chlorine Institute (2).

It should be noted, however, that many waters have no definite

break-point. In fact, it appears that water devoid of ammonia or having even as much as 0.05 p.p.m. will rarely show a definite "point." The curves of Figs. 1 and 2 illustrate such a water. In Fig. 1, the ammonia, being almost negative, there is no indication of a "point." In Fig. 2, however, with 0.02 p.p.m. ammonia there develops almost a true "point." Waters which have no break-point may be pre-chlorinated without regard to this optimum. Instead, the amount of chlorine to be added to the raw water then becomes that which is found necessary to maintain, at all times, the desired minimum at the point of de-chlorination.

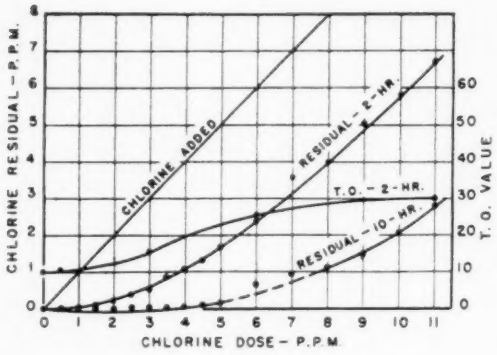

FIG. 1

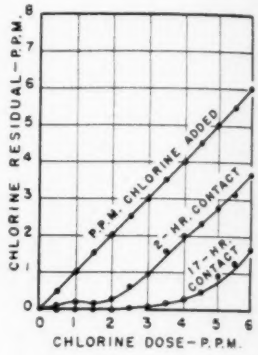

FIG. 2

FIG. 1. Relation of Chlorine Dose to Chlorine Residual for water of the following analysis: temperature, 24°C.; bacteria, 100 per ml.; algae, 600 per ml.; turbidity, 42; color, 45; alkalinity, 38; oxygen consumed, 6.4; T.O., 12; pH, 7.4; ammonia, 0.0075

FIG. 2. Relation of Chlorine Dose to Chlorine Residual for water of the following analysis: temperature, 23.5°C.; bacteria, 60 per ml.; algae, 480 per ml.; turbidity, 8; color, 30; alkalinity, 46; oxygen consumed, 4.2; CO_2, 1.8; pH, 7.3; ammonia, 0.02

The plant which treats a raw water of a definite break-point is fortunate, unless the "point" should require more chlorine than is practical. One of the characteristics of the break-point is the remarkable reduction in taste and odor, as well as in the residual chlorine which results when it is reached. Thus, a water may be chlorinated to the break-point and yet require neither de-chlorination nor taste correction.

For those supplies which are troubled with taste and odors and in which the use of activated carbon is not practical because filtration is not required, break-point chlorination may prove invaluable.

De-Chlorination

An interesting proof of the correctness of a statement made by one of the authors (3) is shown by Fig. 1. Since using de-chlorination at Richmond, the quantity of chlorine used has been increased. Figure 1 shows that the tastes and odors of the raw water have more than doubled because of this increase in chlorine. Despite the increase in taste in the raw water, however, no additional carbon is required to give the same threshold odor in the finished water. In other words, even though no break-point is found, the persistency of the tastes and odors is not increased. Hence, super-chlorination (using the second definition) has not actually been reached.

There are available several effective de-chlorination methods. Of these, the most generally used in large plants is the sulfur dioxide method. For smaller plants sodium bi-sulfite may be preferred, and sodium thio-sulfate and activated carbon should also be mentioned.

In theory, the following reactions occur when sulfur dioxide is used:

$$H_2O + SO_2 = H_2SO_3$$
$$H_2O + Cl_2 = HClO + HCl$$
$$HClO + H_2SO_3 = HCl + H_2SO_4$$
$$SO_2 + Cl_2 + 2H_2O = H_2SO_4 + 2HCl$$

Theoretically the quantities involved are 0.905 p.p.m. of sulfur dioxide per 1 p.p.m. chlorine to be reduced. As an example, if a residual of 1.2 p.p.m. chlorine is to be reduced to 0.2 p.p.m., 0.905 p.p.m. sulfur dioxide will be required.

At Richmond, in winter, the raw water is de-chlorinated to 0.2 p.p.m. of chlorine immediately before filtration. This quantity is selected because it is the minimum residual which is believed to be certainly effective as a sterilization agent. In summer, the residual is increased to approximately 0.4 p.p.m. to prevent growths of organisms in the filters.

Liquid sulfur dioxide is purchased in steel containers, similar to the ton chlorine units, so that they may be handled with the same mechanical equipment that is used for the chlorine. The amount of dioxide used at any time is that required to produce the desired chlorine residual, as determined by the ortho-tolidine test. Therefore, no control except a pressure-reducing valve, to maintain a constant low pressure on a standard control needle valve, and a three-

way cock, to avoid vacuum in the feed pipe when shutting down, is needed.

It may be interesting to note that the amount of chlorine used in the raw water at Richmond for July and August, 1939 and 1940 averaged approximately 38½ lb. per mil.gal. for a moderate super-chlorination. The quantity of sulfur dioxide used, depending as it does upon the ratio of the actual to maximum sunlight hours, varies between wide limits. As an example of this variation, during one month in which an average of 42.28 lb. per mil.gal. of chlorine was used for pre-chlorination, only 1 lb. per mil.gal. of sulfur dioxide was used for de-chlorination; and in the following month, with only 35.2 lb. per mil.gal. for pre-chlorination, 2.2 lb. per mil.gal. sulfur dioxide was required for de-chlorination. This very variation in the use of sulfur dioxide, however, is the greatest single indication of its value in plant operation.

Conclusion

In closing—even at the risk of being unorthodox—is it not in order to realize the tendency of the water purification profession to become super-faddist? Too often new ideas are hailed as panaceas. We rush their adoption, later to realize that while we have found an improvement, we still have our problems. So let us not expect super-chlorination or break-point chlorination to prove, at best, more than a step forward in our progress to perfection. Surely, though, with such benefits as improved coagulation and sand beds, complete sterilization, exact control of chlorine residual, stabilized settling basins, and reduced tastes and odors as possible and even probable rewards, every operator should at least investigate super- and de-chlorination.

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Zeolite Softening at South Orange, N. J.

By Robert Spurr Weston

IN THE summer of 1938, the Village of South Orange authorized an investigation of the advisability of softening its water, taken from wells driven in rock, to depths as great as 382 feet, in the Rahway River Valley. Recommendations of the investigators were followed and design and construction of a zeolite plant were projected. Now, for over eleven years, the water has been softened by the zeolite process, and, during the period, changes in plant, in process and in results of operation have taken place.

In April, 1929, when water softening began, population of the village was about 13,100 and water consumption, 396 mil. gal. per annum, or 82 g.p.d. per capita. Present population is 13,750, and consumption, in 1939, was 477.216 mil. gal., or about 95 g.p.d. per capita; whereas, in 1931, it had been estimated that the 1939 population would be 19,200 and consumption 550 mil. gal. per annum, or 78 g.p.d. per capita. The changes in population and consumption over the years are shown in Fig. 1.

The earliest supply of the village was from a group of ten air-lift wells, averaging about 300 ft. in depth. Not all of these wells, however, give good yields, their combined output being less than 1.3 m.g.d. Ordinarily, now, the wells are held in reserve and operated for only a few hours each month.

The present main supply comes from three deep wells having a combined capacity of about 1.7 m.g.d. One of the wells is also used for the supply of a lake in the village park, and when it is used for this purpose, capacity for water supply is reduced to below 1.5 m.g.d.

While it is estimated that at least 3 m.g.d. may be obtained from wells in the valley, and while the State Water Policy Commission

A paper presented on October 19, 1940, at the New Jersey Section Meeting, Atlantic City, N. J., by Robert Spurr Weston, Consulting Engineer, Weston & Sampson, Consulting Engineers, Boston.

has granted the village rights to 2 m.g.d. therefrom, the present development is inadequate. Early in 1940, the ground water level was lowered to such a degree that the additional lift required for supplying the softening plant could not be provided; so, between February 7 and April 25, it was necessary to take the plant out of service. During this period, consumption was only 1.29 m.g.d. and the air-lift wells were drawn upon frequently. Additional deep wells have been advised but have not yet been driven.

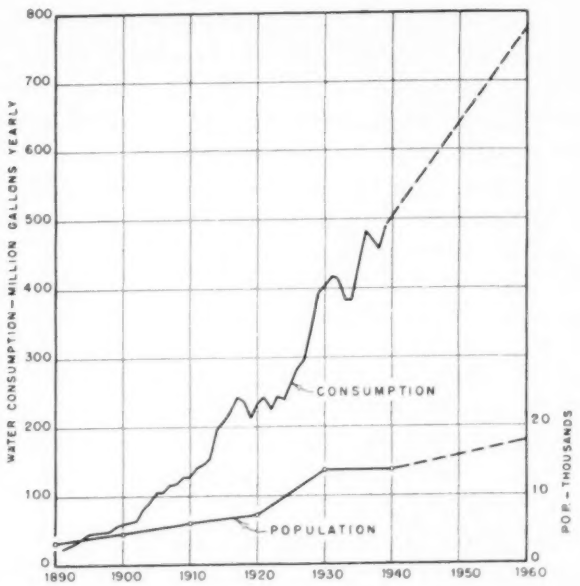

FIG. 1. Relation of Growth of Population to Increase in Water Consumption in South Orange

Characteristics of the raw water are given in Tables 1 and 2. It is obvious from these data that the water is excessively hard, but otherwise suitable for domestic use and safe for drinking.

Studies on Zeolite Softening

The writer's introduction to the work of softening was through Major Arthur H. Pratt, then chief engineer of the North Jersey District Water Supply Commission and a resident of South Orange. The realization of the project was due to the work of the Village

Water Commission, of which O. D. Frost was chairman at the time, and of the late Ira T. Redfern who was village engineer.

Studies leading to design began in June, 1928. The village received several proposals for softening plants containing synthetic

TABLE 1

Typical Analysis of Raw Water, June 11, 1928

	p.p.m.		p.p.m.
Turbidity	0.0	Total Residue on Evaporation	311.0
Color	0.0	Loss on Ignition	86.0
Nitrogen (as Nitrates)	4.0	Mineral Residue on Evaporation	225.0
Chlorine	25.0	Carbon Dioxide	17.0
Sulfuric Acid (SO_4)	59.2	Silica, and Iron and Aluminum Oxide	6.0
Alkalinity	120.0	Calcium	67.9
Hardness (by soap method)	162.8	Magnesium	7.0
Iron	0.015		
Manganese	0.0		

TABLE 2

Hardness and Other Significant Constituents of Raw Water, 1929–39

YEAR	HARDNESS			AVERAGE CONTENT OF OTHER SIGNIFICANT CONSTITUENTS					
	Ave.	Max.	Min.	Chlorides	Alkalinity	Free CO_2	Sulfates (SO_4)	Iron	pH
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	
1929	140	168	128	21.7	140	—	—	0.10	7.1
1930	142	155	128	29.5	113	18	47.3	0.03	7.2
1931	143	169	121	33.0	105	—	—	0.026	6.8
1932	185	204	157	38.5	130	32	65.8	0.07	6.8
1933	154	184	126	20.4	107	43	—	0.05	6.7
1934	150	160	138	19.3	171	48	—	0.03	6.7
1935	155	196	138	19.8	125	38	—	0.023	6.7
1936	173	203	156	18.6	114	40	—	0.15	6.7
1937	153	168	132	15.9	112	40	—	0.02	6.7
1938	151	172	136	15.2	111	37	—	0.05	6.7
1939	156	188	148	17.0	112	38	—	0.04	6.7
Averages	155	179	137	22.6	122	40*	—	0.055	6.7*

* Deep wells only. When air-lift wells are in operation CO_2 is lowered.

zeolite (silica gel) or green sand (Glauconite). Two of the estimated cost schedules for softening 900 g.p.m., based upon the contractors' proposals for softeners containing artificial and natural zeolites, were as shown in Table 3.

Partly because of the more favorable financial showing and partly because of the smaller space required for installing a plant using the more efficient synthetic zeolite, the village, on September 14, 1928, awarded the contract for three 8-foot Crane-Warlo softening units, containing Doucil, to the Turbine Equipment Co.

In addition to the softening units, the work included storage for raw and softened water, 35,000 gal. of the raw to cover variations in pumping from the wells and to provide water for washing the softeners, and 22,000 gal. of the softened to modulate differences between rates of softening and of high-lift pumping.

Because it was thought sufficient to reduce the hardness of the delivered water to 35 p.p.m., a "make-up" pump was installed to

TABLE 3

Comparative Costs of Softening With Natural and Synthetic Zeolites

ITEM	COST PER MIL. GAL.	
	Synthetic Zeolite (Doucil)	Natural Zeolite (Permutit)
Salt consumption as guaranteed	$21.55	$21.55
Zeolite waste, 3%	0.59	0.86
Power @ 1.6¢ per kw. hr.	2.44	3.70
Labor	4.58	5.20
Pumping wash water	0.01	0.04
Total operation costs	$29.17	$31.35
Fixed charges @ 6.5%	6.12	5.15
Total cost of softening	$35.29	$36.50

take raw water from the raw water basin and discharge it into the soft water basin.

Softening by zeolite is a base-exchange process. Synthetic zeolite is a silica gel containing sodium. When water containing calcium or magnesium, or both, is brought into contact with the silica gel, the sodium in the zeolite exchanges with the calcium and magnesium in the water until its power is exhausted. It is then regenerated with a solution of sodium chloride (brine) which displaces the calcium and magnesium. The excess of salt is then washed out and the zeolite is ready for another softening operation.

The chemical formulas descriptive of this and similar actions have been described elsewhere so frequently that repetition here would be superfluous.

Design of Plant

The contractor installed, in the former boiler room of the pumping station, three softeners, each 8 ft. in diameter, and containing 125 cu.ft. of Doucil (CW-40) manufactured by the American Doucil Company of Philadelphia.

Each unit had a rated capacity of 136,450 gal. between regenerations when operating with water having a hardness of 188 p.p.m., and the three units a normal combined discharge rate of 850 g.p.m. Because of opposing patents (expired in 1932) flow was necessarily upward through the zeolite. This necessitated a system of outlet strainers of the well-tube type. These corroded and clogged, and, at times, stoppages for repairs became necessary. At present, the flow through the units is downward. The strainers have been turned upward and left in the units.

Cars, operating on a spur track, bring salt for regeneration. From the cars, the salt is discharged into two concrete storage tanks provided with underdrains of gravel and sand. The salt is covered with water and the concentrated brine flows by gravity into a sump from which a 15-g.p.m. centrifugal pump discharges it into the brine-feed tank.

For regenerating the zeolite, brine is taken from the feed tank by means of a water injector which discharges diluted brine to the softener units. A float-controlled valve, which may be set for any depth, governs the depth of discharge from the feed tank.

Each softener unit and the wash-water waste-pipe are equipped with meters of the Venturi type with Brown indicating dials, as well as with recorders including totalizers.

The plant was placed in operation in June, 1929, and the results for the year 1930 were as shown in Table 4.

By 1931, the maximal rates of softening had reached 180 per cent of the average; so in December of that year, a fourth, a Ward-Love, softener unit was installed under the supervision of the Permutit Company of New York. At the same time, the old units were emptied and a layer of graded gravel 14 in. in thickness was placed in each one. On December 10, 1931, the old units were replaced in service. The new unit was placed in service on January 6, 1932.

During the changes, it was noted that the lower layers of Doucil were disintegrated and befouled with iron rust, and that both its volume and efficiency had decreased. This decrease is shown strikingly in Table 5.

The decrease in yield caused deterioration and loss, the Doucil being extremely sensitive to water having a pH value of less than 7.0. Because water could be obtained more economically from the new wells, the use of the air-lift wells had been restricted, with consequent

TABLE 4

Operating Results for 1930

Volume:	
Water softened, *mil. gal.*	314.36
Water delivered to mains, *mil. gal.*	403.18
Make-up water, *mil. gal.*	81.32
Water delivered unsoftened, *mil. gal.*	7.50
Salt Used:	
For regeneration, *tons*	862.41
For regeneration, *lb. per mil. gal.*	5,487
Per regeneration, *lb.*	732
Volume of water softened between regenerations, *gal.*	131,808
Percentage of wash water, %	2.21
Average period of washing, *min.*	24.7
Average consumption, *m.g.d.*	1.084
Average hardness:	
Well water, *p.p.m.*	140
Softener effluent, *p.p.m.*	0
Delivered water, *p.p.m.*	35
Average chlorine content:	
Well water, *p.p.m.*	29.5
Softener effluent, *p.p.m.*	29.0
Delivered water, *p.p.m.*	35.7

TABLE 5

Equivalent Yield Between Regenerations

PERIOD OF OPERATION	YIELD IN GALLONS
First day, Jan. 6–7	165,200
First week, Jan. 6–13	141,500
Week of March 19–26	110,200
March 26	108,800

loss of aeration and increase in carbon dioxide in the influent to the softeners. To overcome this acid condition, beginning on May 17, 1932, sodium carbonate and sodium silicate were added to the well water, the latter chemical to maintain the silica contained in the zeolite. The combined treatment, while not affecting the hardness

raised the alkalinity from 130 to 157 p.p.m. and the pH value from 6.8 to 7.2. These increases were accompanied by a decrease in carbon dioxide of from 31 to 11 p.p.m.

After regeneration and after chemical treatment, the yield between regenerations of the treated Doucil, based upon a raw water hardness of 186 p.p.m., was: for May 24, 1932, 141,270 gal.; and for June 8–10, 1932, 142,595 gal.

Thus, by treatment, the performance of the old Doucil was brought within 2 per cent of that of the new material.

Before chemical treatment began, the other units—Nos. 2, 3, and 4—were rehabilitated. The lower 5 in. of Doucil from each unit were discarded and the remaining good material from unit No. 2

TABLE 6

Yields of Remodeled Units, June 10, 1932

UNIT	ZEOLITE	YIELDS	
		Gal. per 24 hr.	Gal. Between Regenerations
No. 1	Doucil	290,049	142,526
No. 2	Decalso	309,350	135,715
No. 3	Decalso and Doucil	298,195	142,760
No. 4	Decalso and Doucil	241,960*	135,830
Mean		284,888	139,208
Weighted Average			138,566
Guaranteed Yield			136,363

* Low yield due to clogged strainers.

was placed in Nos. 3 and 4. Unit No. 2 was then filled with "Decalso," as recommended by the Ward-Love Pump Corporation* and its associate, the Permutit Company; and the zeolite in Nos. 3 and 4 was brought to its proper level by the addition of Decalso.

On June 10, 1932, the yields of the remodeled units were as shown in Table 6.

Chemical Dosage and Costs

The doses and costs of the additions of chemicals are given in Table 7. Naturally, the cost of soda ash and silicate, in addition to that of salt for regeneration, placed a decided burden upon the plant. In 1934, the cost of soda ash at $2.08 per 100 lb. amounted to $3,916,

* Formerly a division of the General Water Treatment Corporation.

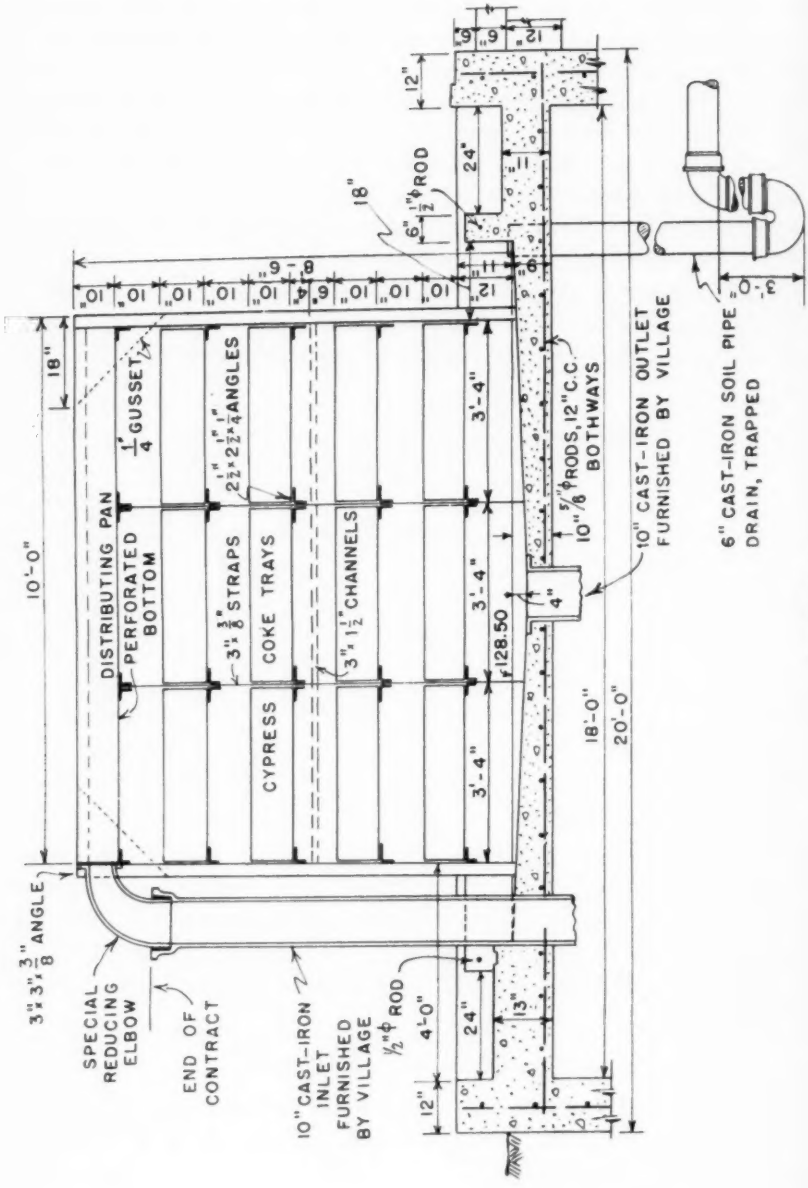

FIG. 2. Aerator

or $12.40 per mil. gal.; and that of sodium silicate at $1.33 per 100 lb., to $736, or $1.73 per mil. gal.—a total of $4,649, or $14.13 per mil. gal., 29.5 per cent of the total cost of $47.99 per mil. gal. Because of this disproportionate cost, it was decided to resort to aeration.

Aeration

The aerator (Fig. 2) consists of four superimposed trays filled with coke, each tray being made up of fifteen boxes with copper wire-cloth bottoms, containing a depth of 10 in. of coke. Each box is supported by a frame-work of steel resting on the floor of the shallow aerator basin. The distribution of water taken from the well-water main is effected by a perforated pan placed above the topmost coke tray.

TABLE 7

Doses and Costs of Chemicals per Million Gallons Softened

YEAR	SODIUM CARBONATE		SODIUM SILICATE	
	Dose	Cost	Dose	Cost
	lb. per mil. gal.		*lb. per mil. gal.*	
1932*	71	$1.31	111.4	$1.45
1933	437	9.48	161.8	2.07
1934	596	12.40	129.7	1.73
1935†	396	8.16	85.4	1.20
1936	—	—	24.5	0.37
1937	—	—	23.8	0.25
1938	—	—	9.8	0.095
1939	—	—	8.5	0.084

* Beginning in May. † Discontinued on March 11.

When this addition was submitted to the health authorities for approval, they advised that it be housed. Consequently, the aerator was placed in a building, 18 ft. x 18 ft. inside, with walls 9.5 ft. high and a pyramidal roof. In the walls of the house were placed 68 removable air filters, each 20 in. square; and an "Effico" automatic wind-electric ventilator, 24 in. in diameter, was set in the apex of the roof.

The total area of filters is 189 sq.ft., and the fan is designed to provide the same amount of movement of air as would be produced by a wind velocity of 5 m.p.h. With higher velocities, the degree of ventilation is increased. The fan is not necessary when the wind

velocity is high and is often put out of service in winter because of accumulations of ice on the fan blades.

In the beginning, "Renn-Vent" air filters were used, but mischievous visitors poked holes in the steel wool of which they were constructed, and, after several years of service, they were destroyed by corrosion. Early in 1939, the corroded air filters were replaced with "Dustop" filters, which, made of spun glass, have withstood the inconsiderate efforts of visitors much better, and which also are rust-proof.

Results of tests on reduction of carbon dioxide are shown in Table 8.

TABLE 8

Reduction of Carbon Dioxide Through Aeration

DATE	CARBON DIOXIDE	
	Well Water	Aerated Water
	p.p.m.	*p.p.m.*
April 22, 1936	40.0	10.5
October 9, 1937	31.1	12.8
May 10, 1938	37.0	8.0
July 31, 1938	37.0	7.5
October 3, 1938	42.5	12.7
June 16, 1939	41.8	14.0
Sept. 5, 1939	36.3	10.2
Sept. 17, 1940	43.0	8.0
Average	38.4	10.6

Tests of aerator efficiency with the fan not operating were made on September 27, 1940, at a temperature of 73°F. and with a low wind velocity. Carbon dioxide reduction under these conditions was from 43.0 p.p.m. in the aerator influent to 8.0 p.p.m. in the effluent; and dissolved oxygen concentration increased from 45 per cent saturation to 98 per cent, from influent to effluent. While these efficiencies do not compare favorably with those of uncovered aerators, they still seem adequate.

General arrangement of the plant with the aerator is shown in Fig. 3, and the softening units with meters are shown in Fig. 4.

Notwithstanding the benefits due to aeration, it was not thought wise to discontinue the addition of sodium silicate; but, at this

writing, doses of silicate have been greatly reduced, as shown in Table 7. While the application of this chemical might be discontinued without harm, a conservative course is being followed.

Losses of Zeolite

When the softeners were installed, the loss of zeolite was specified to be not more than 3 per cent of its volume per annum. Each unit,

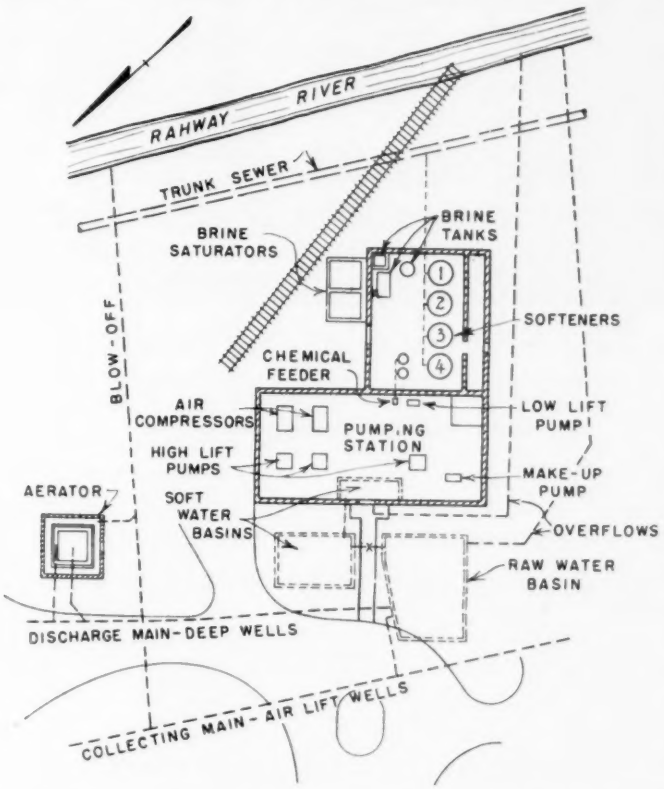

FIG. 3. Layout of Pumping Station and Softening Plant; showing tie-in of Aerator

when installed, contained 125 cu.ft. This limit is equivalent to 3.75 cu.ft. per annum, or 11.25 cu.ft. for three units.

In a unit, 8 ft. in diameter, the depth of 125 cu.ft. is equivalent to 29.8 in. Therefore, the loss limit is a depth of 0.9 in., or more if the units contained more than 125 cu.ft. of zeolites in the beginning.

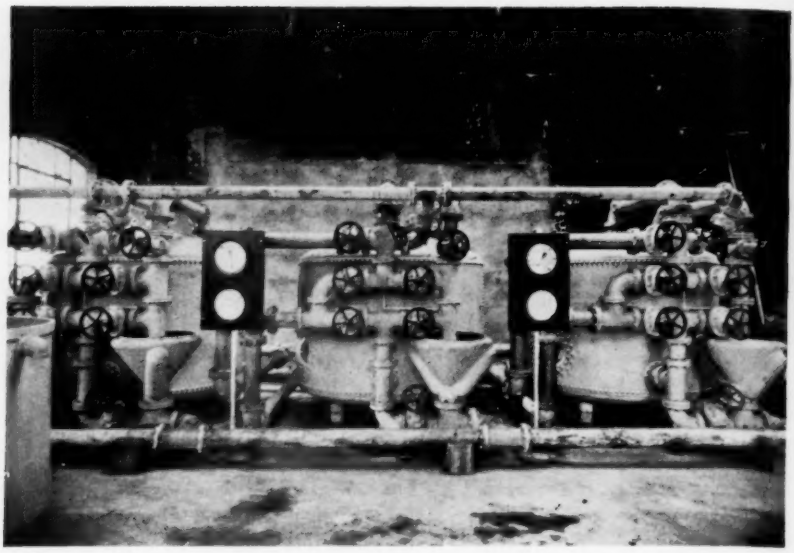

FIG. 4. Softening Units; showing meters attached

TABLE 9

Record of Depth of Zeolites in Service

RECORD	DEPTHS OF UNITS			
	1	2	3	4
	in.	*in.*	*in.*	*in.*
Lost in service to January, 1937	13.0	3.75	10.75	8.25
Replaced, March 1, 1937	29.8	2.5	—	—
Lost in service to January 2, 1938	2.25	2.0	4.5	4.0
Replaced, June 1938	1.9	5.5	29.8	29.8

TABLE 10

Losses in Volume of Zeolite, May, 1932 to July, 1936

UNIT NO.	VOLUME OF ZEOLITE	LOSS
	cu. ft.	%
1	138	32.0
2	125	9.1
3	145	23.
4	140	26.0
Average	137	22.5

Owing to the high carbon dioxide content of the water, the original zeolite lost efficiency rapidly, although there was little loss in volume during the first year. Afterwards, the loss in volume was considerable. After May, 1932, when the fourth unit was installed, a record of depths was kept, as shown in Table 9.

The volumes of zeolite placed in the units in May, 1932, and the percentages of loss on July 2, 1936—more than four years later—are shown in Table 10. The average loss per annum during this period was 7.6 cu.ft. per unit, or 5.62 per cent, equivalent to a depth of 1.81 in. The least loss was shown by new Decalso in unit No. 2.

Up to January 1, 1940, all of the Doucil had been replaced with Decalso, and up to June 29, 1938, the total loss of zeolite was 11.9 per cent per annum. Since July 1, 1938, the loss has been 2.5 per cent per annum.

A large part of the loss, particularly of Doucil, was due to the use of upward flow and consequent losses through openings in worn-out outlet strainers. Because the ordinary life of these strainers is about five years, they had to be renewed—the last at a cost of $324. Since April, 1939, downward flow with aeration has been practiced, and losses have been reduced to below the limit of 3.0 per cent per annum.

Results of Operation

The periods of operation and the percentages of softened and unsoftened water delivered to the mains, as well as the hardnesses of the raw, softened and delivered waters, are shown in Table 11.

The average performances of the plant in terms of grains and pounds of hardness per cubic foot of zeolite, based on the average hardnesses of the raw water, are shown in Table 12.

The original Doucil had a guaranteed capacity of 12,000 grains, or 1.69 lb. per cu.ft.; and later additions of Doucil and Decalso, 9,000 grains, or 1.28 lb. per cu.ft.

Before the carbon dioxide content was reduced, the zeolites lost capacity rapidly; afterwards their capacities exceeded the guarantees of their makers.

The performances of units, subsequent to 1931, in gallons per cycle, *i.e.* between regenerations, are given in Table 13.

Regeneration of Zeolite

Until June 29, 1938, the units were regenerated with new brine. Afterwards, used brine was employed for part of this work. The average periods of regeneration, of rinse, of softening, of periods

TABLE 11

Operation Data, 1929–39

YEAR	DAYS IN SERVICE	BREAK-DOWN OF WATER HANDLED			HARDNESS		
		Makeup	Softened	Delivered Unsoftened	Raw Water	Softened Water	Delivered Water
		%	%	%	*p.p.m.*	*p.p.m.*	*p.p.m.*
1929	274*	18.2	81.8	0.0	140	0	27.3
1930	358	18.6	80.5	1.9	140	0	35.0
1931	330	17.5	73.1	9.4	142	25.8	39.8
1932	314	16.1	70.4	13.5	185	1.6	39.2
1933	227	11.9	48.5	39.6	154	0.0	35.6
1934	365	19.4	80.6	0.0	150	0.0	42.2
1935	365	15.4	84.6	0.0	155	2.0	46.4
1936	366	12.6	87.4	0.0	173	7.9	39.9
1937	363	12.6	87.1	0.3	153	3.8	31.1
1938	355	15.1	81.9	3.0	151	1.2	33.9
1939	355	16.3	81.0	2.7	156	1.3	33.6
Averages, 1934–39.....	361.5	15.2	83.8	1.0	156	2.7	37.8

* April to December, inclusive.

TABLE 12

Data on Plant Performance, 1929–39

YEAR	MEAN ZEOLITE CAPACITY	
	In grains per cu. ft.	In lb. per cu. ft.
1929	10,600	1.52
1930	8,860	1.27
1931	7,630	1.09
1932	9,140	1.31
1933	9,080	1.30
1934	9,140	1.30
1935	10,160	1.45
1936	11,700	1.67
1937	9,310	1.33
1938	9,290	1.33
1939	9,826	1.40

TABLE 13

Performance of Softener Units

YEAR	UNIT NO. 1		UNIT NO. 2		UNIT NO. 3		UNIT NO. 4	
	Zeolite	Gal. per Cycle	Zeolite	Gal. per Cycle	Zeolite	Gal. per Cycle	Zeolite	Gal. per Cycle
1932	New Doucil	132,688	Decalso*	124,908	Doucil and Decalso*	126,072	Doucil and Decalso*	118,427
1933	" "	139,159	"	138,546	"	132,371	"	127,157
1934	" "	140,278	"	131,227	"	127,769	"	123,887
1935	" "	139,488	"	137,230	"	124,400	"	123,521
1936	" "	120,400	"	141,054	"	123,606	"	116,264
1937	Doucil and 8 cu. ft. new Decalso	127,420	Doucil and 10 cu. ft. new Decalso	133,336	New Decalso†	107,463	New Decalso†	109,030
1938	"	145,565	"	126,525	" "	119,717	" "	119,843
1939	"	130,145	"	135,662	" "	128,372	" "	122,669
Average		134,393		133,561		123,721		120,100

* After May. † After July 2.

TABLE 14

Regeneration Statistics

YEAR	PERIOD OF REGENERATION	PERIOD OF RINSING	WASH WATER	AVERAGE PERIOD OF SOFTENING	AVERAGE PERIOD BETWEEN REGENERATIONS
	min.	*min.*	%	*hr. per day*	*hr.*
1929	37.2	23.6	1.72	18.22	9.16
1930	36.4	24.7	2.21	15.98	7.24
1931	35.9	23.9	2.64	16.47	5.95
1932	39.3	26.5	2.78	15.10	7.20
1933	39.5	28.0	2.27	12.77	8.37
1934	39.6	28.0	2.33	12.79	7.91
1935	39.5	28.0	2.32	14.40	7.57
1936	39.5	28.0	2.44	15.83	6.83
1937	39.6	28.0	2.58	15.76	6.64
1938	52.1	45.2	2.21	15.82	7.58
1939	67.2	65.0	2.36	16.61	7.39
Average 1929–37	38.5	23.4	2.36	15.26	7.43

between regenerations, and also percentages of water used for rinsing, are given in Table 14.

A good grade of rock salt is used for regeneration. Table 15 gives a typical analysis of its constituents.

TABLE 15

Typical Analysis of Rock Salt

CONSTITUENT	%
Sodium Chloride ($NaCl$)	97.07
Calcium Chloride ($CaCl_2$)	0.096
Calcium Sulfate ($CaSO_4$)	1.510
Iron and Aluminum Oxide ($Fe_2O_3 + Al_2O_3$)	0.037
Insoluble	0.58
Undetermined	0.707
	100.000

TABLE 16

Data on Salt Consumption

YEAR	WATER SOFTENED	SALT USED			HARDNESS		PARTS OF SALT PER PART OF HARDNESS*
		Tons	lb. per mil. gal.	lb. per regeneration	p.p.m.	lb. per mil. gal.	
	mil. gal.						
1929	246.80	641.35	5,197	826	139.9	1,167	4.46
1930	314.36	862.41	5,487	723	142.2	1,186	4.62
1931	305.67	994.22	6,505	709	142.6	1,190	5.47
1932	291.54	1,119.35	7,675	828	184.8	1,542	4.97
1933	185.97	550.94	5,925	795	153.5	1,281	4.63
1934	308.73	874.68	5,666	741	150.0	1,251	4.53
1935	364.81	1,101.63	6,040	793	155.0	1,293	4.67
1936	423.97	1,243.42	5,866	733	173.0	1,443	4.07
1937	409.27	1,131.24	5,528	655	153.0	1,276	4.33
1938	377.27	953.16	5,053	637†	151.0	1,260	4.01
1939	399.62	838.07	4,194	542	156.0	1,301	3.22

* Grams or pounds.

† Average of two doses: 810 lb. per regeneration from Jan. 1 to June 28, 1938; and 465 lb. from June 29 to Dec. 31, 1938.

Because it is strained through the underdrains of the storage tanks to which the salt is brought, and in which it is dissolved, and because of further subsidence in the saturated-brine tank, the brine is practically free from suspended matter.

The amounts of salt used, and the relations of these amounts to volumes of water softened and to amounts of hardness, are given in Table 16 and shown, in part, in Fig. 5.

In the beginning, the maker's guarantee was 750 lb. of salt per regeneration. Re-use of brine has reduced this by about 30 per cent. On the other hand, the increased time required for regeneration by the re-use of brine has reduced the capacity of the plant by about 5.6 per cent.

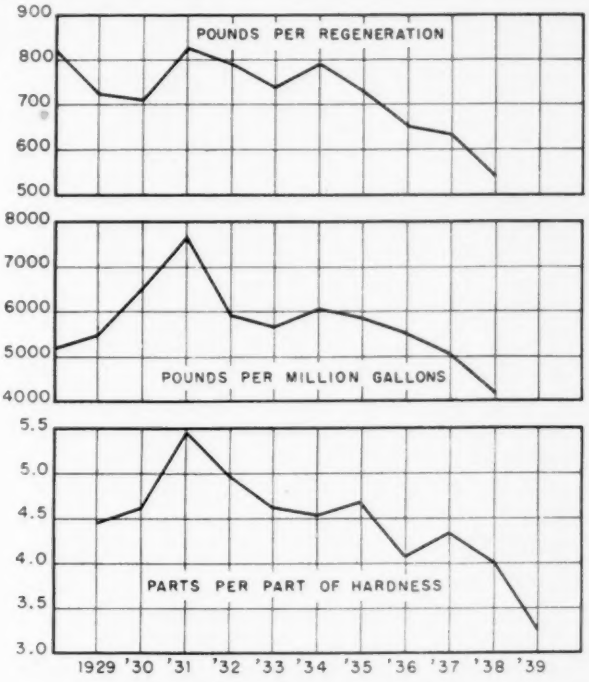

FIG. 5. Salt Consumption, 1929–39

Brine Reclamation and Re-Use

Beginning on June 29, 1938, and at the suggestion of the Permutit Company, a part of the brine used in each regeneration of zeolite has been reclaimed, stored, and re-used. The process, which involves special devices, has been patented, although the principle of counter-current application of solutions in chemical processes is, of course, one of the fundamentals of chemical engineering. The arrangement of the devices is illustrated by Fig. 6. Operation proceeds as follows:

Regeneration starts with the brine tank full of used brine. The volume stored is roughly equivalent to that of the volume of the zeolite and supporting gravel in the softener unit—185 cu.ft., or 1,380 gal.

The pump is started, and used brine is delivered to the softener. When the proper amount, which may be varied, has been introduced to the unit, the float switch on the tank completes the circuit which stops the used brine pump and energizes the solenoid valve on the new brine feed tank. This solenoid valve admits pressure water to a diaphragm valve which admits pressure water to the ejector. The

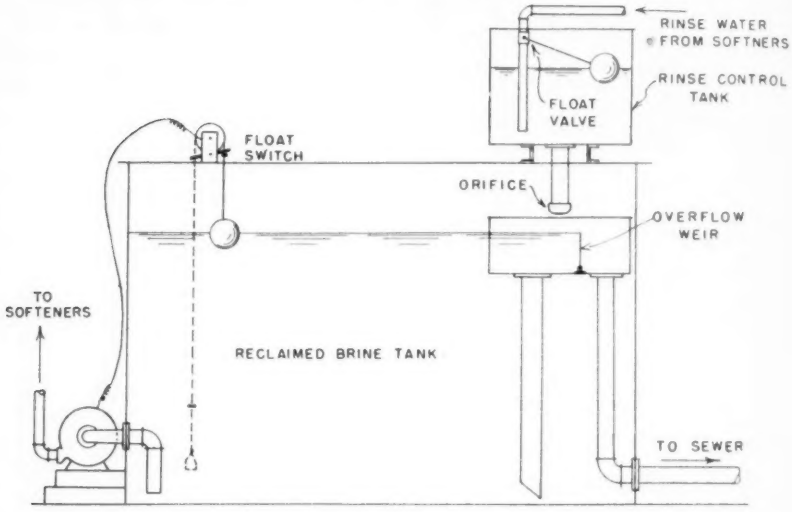

FIG. 6. Brine Reclaiming System

ejector, in turn draws a determined amount of new brine from the feed tank and admits it to the softener. When the proper amount of fresh brine, as determined by the setting of the float switch, has been introduced, the switch on the feed tank breaks the circuit and through the chain of valves stops the ejector.

During the operation, the used brine and the new brine have been introduced into the top of the softener, have passed downward through the zeolite bed, and are being discharged to waste. As soon as the last of the new brine is introduced into the softener, the unit remains idle until the operator opens the hard water inlet valve,

thereby introducing hard water above the bed of zeolite. If desired, soft water may be used in place of hard water. The waste valve is then closed, and the used brine is diverted to the top of the used brine tank.

The used brine is first discharged into the "head box" which so regulates its rate of flow that about 45 minutes are required for rinsing the zeolite. The effluent from this head box is then discharged into a second head box in the used brine tank. This latter has two outlets, one which goes to the bottom of the used brine tank and another which discharges to waste. There is a weir or baffle between the two outlets of the secondary head box. The used brine is dis-

TABLE 17

Data on Typical Regenerations

ITEM	REGENERATION A			REGENERATION B		
	Rate	Time	Amount	Rate	Time	Amount
	g.p.m.	*min.*	*gal.*	*g.p.m.*	*min.*	*gal.*
Back wash	400.0	1	400	400.0	1	400
Back wash	75.0	4	300	75.0	5	375
Used brine	62.7	22	1,380	82.0	18	1,480
New brine	94.0	2	188	87.5	2	175
Back wash to used brine tank	55.2	25	(1,380)	57.0	26	(1,482)
Back wash to sewer	81.5	10	815	57.0	15	855
Totals		64	3,083*		67	3,285*

* To sewer.

charged into the part of the tank connected with the used brine tank, and is prevented from flowing to waste. When the used brine tank is filled to the proper elevation, however, the used brine backs up in the secondary head box until the weir is flooded, and any rinse water coming to the tank thereafter overflows to waste.

The arrangement of tanks is designed to reclaim the portion of rinse water which contains a sufficient concentration of salt to be effective in the subsequent regeneration.

As soon as rinsing is complete, and the excess of salt disappears from the rinse water, the operator manipulates the valves and places the unit either in service or in reserve.

Typical regenerations are accomplished as shown in Table 17.

TABLE 18

Average Volumes and Costs of Water Softened, 1929–39

YEAR	WATER SOFTENED†	TOTAL WATER TO MAINS	UNSOFTENED WATER TO MAINS	COST PER MIL. GAL.		
				Operation	Fixed Charges	Softening
	m.g.d.	*m.g.d.*	*m.g.d.*			
1929	1.103	1.103	.000	$22.52*	$6.70*	$29.22*
1930	1.084	1.084	.021	24.77	6.82	31.59
1931	1.145	1.143	.107	27.52	7.13	34.65
1932	1.142	1.287	.154	33.91	9.83	43.74
1933	1.020	1.467	.416	32.78	15.21	47.99
1934	1.049	1.049	.000	35.86	9.20	45.06
1935	1.182	1.182	.000	25.76	9.04	34.80
1936	1.325	1.325	.000	22.65	8.04	30.69
1937	1.292	1.287	.005	25.73	8.33	34.06
1938	1.249	1.254	.039	26.13	8.90	35.03
1939	1.344	1.344	.036	19.07	8.70	27.77

† For days of softening.

* April to December, inclusive.

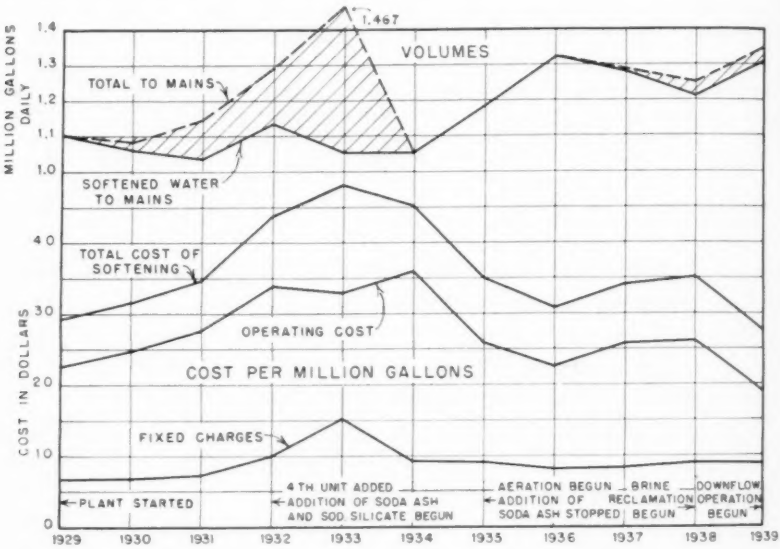

FIG. 7. Relation of Volume of Water Softened to Unit Cost of Softening

Volumes and Costs of Operation

The yearly average volumes of water softened and delivered to the mains, as well as the costs of operation, fixed charges, and total costs of water are shown in Table 18.

Some of the data in Table 18 are shown diagramatically in Fig. 7. In this diagram the effect upon cost of delivering unsoftened water to the mains, as during 1933 when the plant was shut down for three months to save money, and at other times for necessary repairs and additions, is demonstrated.

Savings in Soap

While everyone appreciates that water softening reduces the formation of scale in boilers, adds to the life of laundered fabrics, and makes the use of water more agreeable for most purposes, it is not generally realized how great are the savings in soap and how much these savings affect municipal economy. According to the formula of Hudson (1), the cost of softening at South Orange would be met by a reduction in hardness of 55 p.p.m. Because the actual reduction is 2.2 times as much, the savings are correspondingly increased, and are estimated, for 1939, at $20,200, or twice the cost of softening.

This estimate is based upon a soap cost of $0.145 per pound, which is but little more than the average cost of good laundry soap, about $0.11 per pound. In a residential community like South Orange, where the use of toilet soap, costing from $0.15 to $1.00 a lb., is greater than the average, the saving in soap cost is probably more than estimated according to the Hudson formula. Increased per capita consumption and consequent increased municipal revenue also have followed softer water.

Conclusion

What has been written is a record of a decade of operation. While, fifteen years before the building of the South Orange plant, the writer had been connected with experiments for the Ohio Valley Water Company at McKee's Rocks, Pa., with a hard water containing manganese that led, in 1925, to the building of a plant using Borromite*, a natural zeolite (2), the South Orange plant is believed to be the first municipal (3) plant in which synthetic zeolite was used.

* Furnished by the Wayne Tank and Pump Co.

The South Orange Water Works is in charge of the Village Committee on Water Supply, John H. Bell, Chairman. Robert P. Carter, Chief Operator, and three assistants operate both softening and pumping plants. Arthur L. Demarest, Village Engineer, and Joseph E. Scott, Superintendent of the Water Department, have furnished information about the plant, and the writer is indebted to H. L. Bowers, Service Manager of the Permutit Company, for much information regarding the work done by his company and its affiliates, and to George G. Bogren and others of the writer's firm for material assistance in the preparation of this paper.

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The Water Analysis Laboratory of the Public Works Ministry of Venezuela

By J. M. Sanchis

THE long-felt desire of the Venezuelan people for better living conditions has found an added opportunity of realization in the impetus given to the modernization of water supplies and sewerage systems by special provisions made part of a "Three Year Plan" of national improvements now in progress. Realizing the importance of sound advice for the successful accomplishment of the provisions of the plan, the Ministry of Public Works secured the services of George C. Bunker, Consulting Engineer from Panama, whose long experience with sanitary engineering problems in the tropics has found expression in some of the outstanding water supply and purification projects completed during recent years in Panama and in Colombia.

As a first step, Mr. Bunker established a water analysis laboratory to obtain data for the selection of the most suitable supply available for each community and to determine the extent of water treatment required in localities where it was necessary. The many other duties which demanded attention, however, made it desirable to delegate the responsibility of conducting the laboratory activities to someone else. It was the privilege of the writer to have the opportunity to develop and expand the laboratory and to train its personnel.

The water analysis laboratory is part of one of the divisions of the Direction of Sanitary & Hydraulic Works which, in turn, is one of the six departments through which the diversified activities of the Ministry of Public Works are handled. From a modest beginning, the laboratory has grown steadily during the past two years, and at this time it occupies five ample rooms located in the head-

A contribution by J. M. Sanchis, Chief, Water Analysis Laboratory of the Public Works Ministry of Venezuela, Caracas, Venezuela, South America.

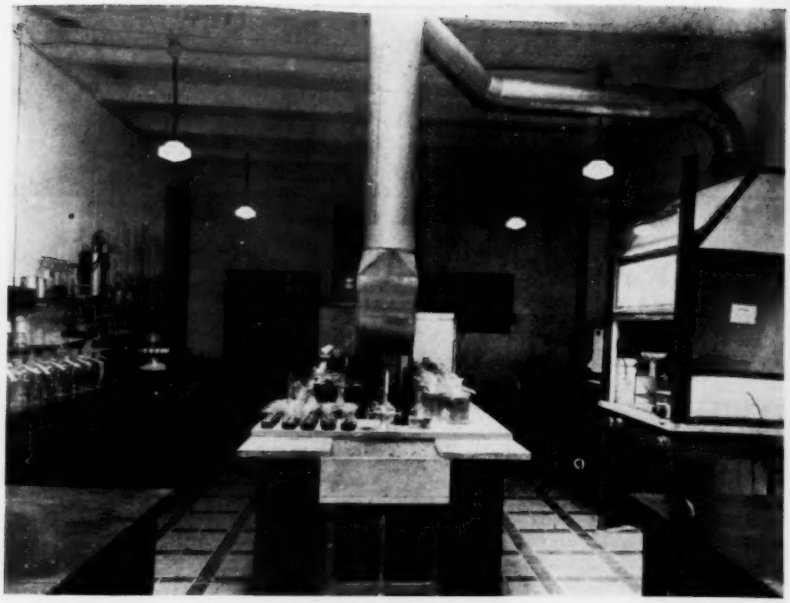

FIG. 1. Mineral Analysis Laboratory

FIG. 2. Close-up of Ventilating Ducts and Fume Hood

quarters building of the Public Works Ministry in Caracas. In addition to the work originally undertaken, the laboratory has assumed, since July 1, 1939, the duties formerly performed by the water analysis laboratory of the Ministry of Public Health, thus bringing under one roof all governmental water examination activities.

The laboratory has been equipped with modern facilities for the performance of complete bacteriological, plankton, mineral and sanitary-chemical examinations of water and sewage. In addition, it also has the necessary equipment for carrying out experiments in water treatment, studies on the corrosive properties of waters and soils, analysis of filter sands, testing of meters and other related activities in the fields of water treatment and supply.

One of the laboratory rooms is used for the performance of mineral analysis. The routine determinations made in this laboratory include: specific electrical conductance, pH, color (apparent and real), turbidity, carbon dioxide, carbonates, bicarbonates, chlorides, sulfates, fluorides, silica, calcium, magnesium, sodium, iron (soluble and total), manganese (soluble and total) and dissolved solids. In special cases, determinations of dissolved oxygen, nitrites, nitrates, aluminum, copper, lead, zinc, boron etc. are also made.

The withdrawal of objectionable vapors from the room is accomplished effectively by means of a "Duriron" exhaust fan, directly connected to a $1\frac{1}{2}$-h.p. motor, installed over the laboratory. The fan aspirates the vapors through a series of openings placed on both sides of a rectangular duct which is supported by the center table (Figs. 1 and 2). The location of the suction duct at this low level was made necessary by the presence of a skylight, with glass louvers, on the laboratory roof. Under these conditions, a standard installation of ventilating ducts would have facilitated the short circuiting of air currents along the ceiling, allowing the objectionable vapors to remain in the working zone.

Another room, of the same size, serves, for the time being, as a three-purpose laboratory (Figs. 3 and 4). One side is used for bacteriological examinations; the other, equipped for the performance of sanitary-chemical analysis; while a portion of the center table is available for plankton work. The remaining space on the center table is used for the preparation of culture media and for whatever other purpose it is needed.

A third laboratory (Fig. 5) houses the apparatus for the performance of water treatment experiments, examination of filter

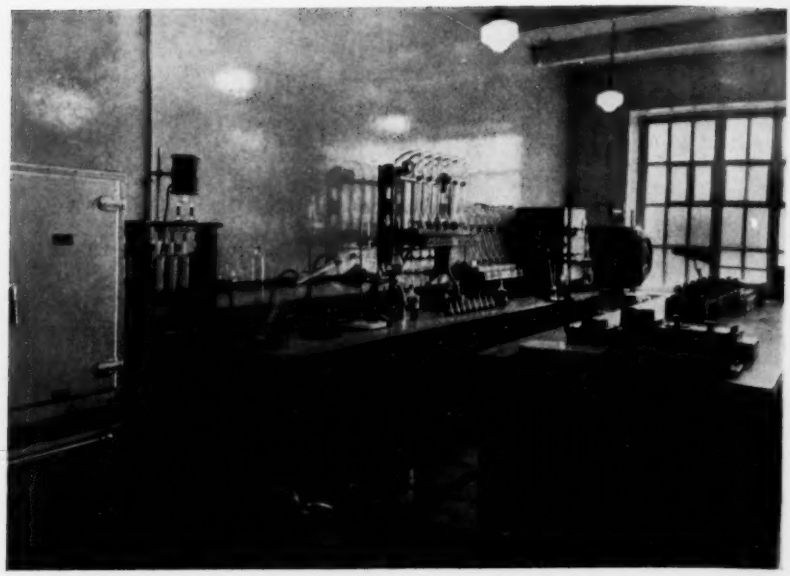

FIG. 3. Section of Combined Laboratory; showing equipment for gas analysis, fluoride and ammonia distillation, organic nitrogen digestion, sterilization of glassware and of culture media, and potentiometric determinations

FIG. 4. Section of Combined Laboratory; showing staining table and bacteriological bench

sands etc., while in an adjacent room (Fig. 6), the meter testing equipment has been installed.

Washing of laboratory ware is accomplished in a well-ventilated space located within easy reach of all the laboratories. Since laboratory supplies have to be imported and delivery is usually delayed for a considerable time, the maintenance of a large and well-stocked storeroom (Fig. 7) is particularly important.

Water samples are usually collected by members of the Ministry of Public Health or by one of the following divisions of the Direction

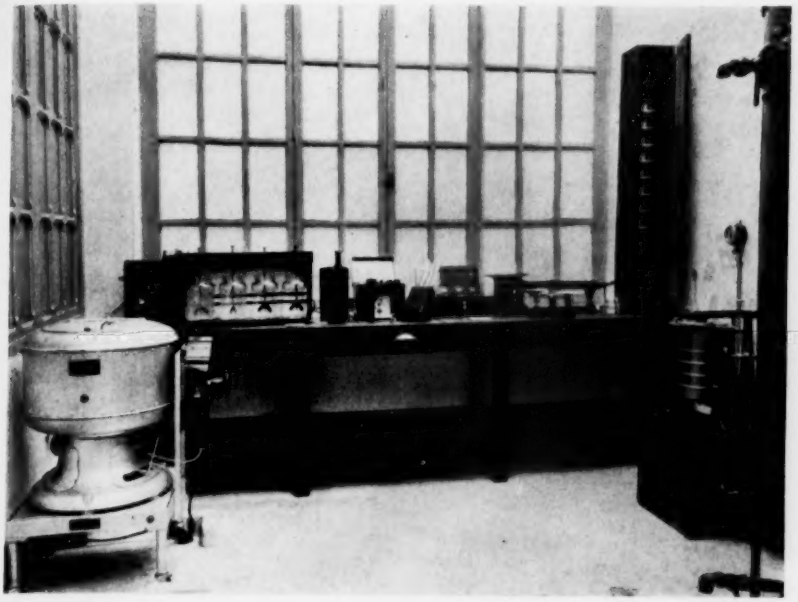

FIG. 5. Meter Testing Equipment

of Hydraulic and Sanitary Works: Division of Aqueducts, Geological Service Division, or Division of Water Analysis.

The samples sent in through the Division of Aqueducts are collected by members of commissions assigned to survey existing water supplies and to obtain additional data on available sources of water in communities where improvements are to be made. In localities where the inadequacy or the undesirable quality of surface waters makes it advisable to investigate underground sources, the members of the Geological Service become the parties chiefly interested in sending laboratory samples from existing wells or from exploratory

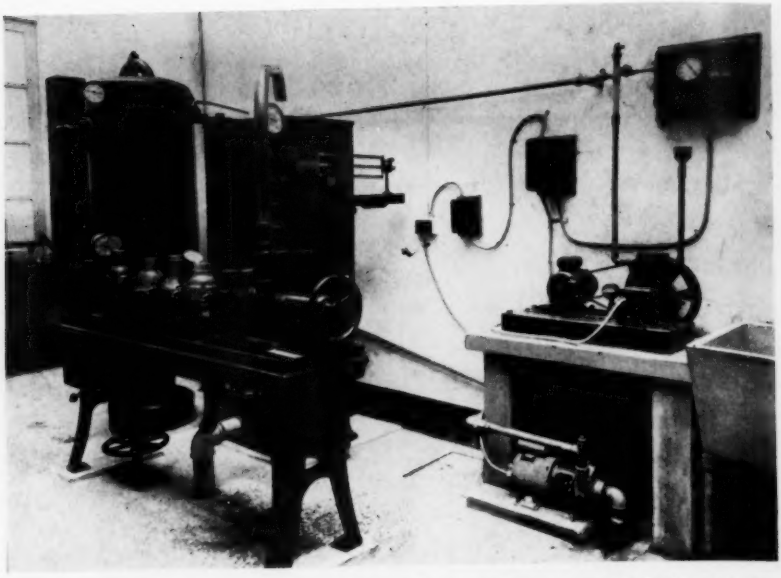

FIG. 6. Water Treatment, Sand Analysis and Special Work Laboratory

FIG. 7. Storeroom

ones put down under their direction. The samples obtained by members of the Division of Water Analysis, are collected, usually, for the purpose of making comprehensive surface and underground water quality surveys in the most important areas, or to obtain long-time records on water quality fluctuations of supplies for which treatment plants are to be provided. Special samples are also collected by members of this division while making sanitary surveys of water supplies at the request of the Direction of Hydraulic and Sanitary Works. The samples sent in by the various divisions of the Ministry of Public Health are usually obtained in connection with epidemiological investigations.

Most of the samples sent to the laboratory are for physico-chemical analysis or bacteriological examination. For the collection of samples for physico-chemical analysis, the laboratory sends out glass-stoppered 2-liter bottles. These bottles are capped, supplied with tags and placed in light wood shipping containers along with standard questionnaires for obtaining all pertinent data in regard to the sampling point and to the water being sampled. A map of the state where the sample is to be collected, is also placed in the shipping container in order to obtain a graphical description of the sampling point.

The bottles used for the collection of bacteriological samples are standard glass-stoppered, wide-mouthed, 4-ounce bottles which have been capped with parchment paper and sterilized in the usual manner. When only one or two samples are needed, and whenever it is possible to have the samples reach the laboratory in less than three hours, the bottles are sent out in individual cylindrical metal containers. For the purpose of insulation, these containers are placed within larger ones, the space between containers being filled by lightly packed paper. By sealing the cover of the inner container with adhesive tape, the empty space can be used for carrying ice. When more than three samples are to be collected, the bottles are shipped in well-insulated double compartment boxes having capacity for eight bottles. The bottles are placed on a removable shelf held by supports above the ice compartment. More recently, the use of standard wide-mouthed thermos jars has been adopted. The jars, which are ten inches high and seven inches in inside diameter, accommodate from one to seven sample bottles. The space between the bottles and the cover is ample enough to hold a twelve-inch ice bag which is used for the refrigeration of the samples. The thermos-

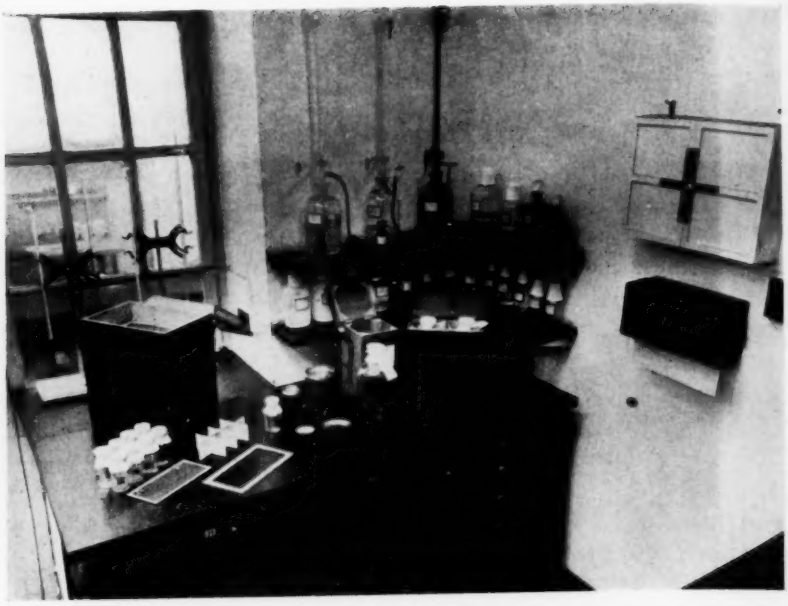

FIG. 8. Sampling Equipment

FIG. 9. Laboratory Personnel: left to right, J. J. Rojas, L. A. Lozada, J. R. Hurtado, J. M. Sanchis, C. A. Rodriguez, M. Soto

jar ice-bag combination has proved extremely practical, both because of its low cost and because of the ease in which it can be carried about in the field. Two fillings of the ice bag, one before starting out to get the samples and the other just before shipping them to the laboratory are sufficient, usually, to keep the samples well refrigerated during an eight-hour journey. Some of the sampling equipment is shown in Fig. 8.

Because of the limited facilities available for rapid land and water transportation, the long distance shipping of bottles is done mainly by plane. Efficient plane service to the larger centers throughout the republic is available. Samples collected in localities which lack air transportation facilities are brought to the nearest airport for shipment. Telegraphic notification of the shipment is made by the sender, so that the samples may be claimed promptly on arrival at Caracas.

The desire of the Ministry is to build up a capable laboratory organization with graduates of the universities of Venezuela. This organization is intended to serve as a nucleus for future expansion of sanitary engineering activities throughout the republic. In keeping with this policy, the members of the laboratory staff, with the exception of the writer, are Venezuelans who, because of their interest and aptitude for laboratory work, have been selected for special training.

The present state of development of this laboratory could not have been realized without the valuable co-operation of Dr. Thomas Pacanins, former Minister of Public Works and of Dr. Hernan Ayala, former Director of Sanitary and Hydraulic Works, under whose term of office the laboratory was established; or without the enthusiastic support given to it by Dr. Enrique J. Aguerrevere, present Minister of Public Works, and by Dr. Juan Francisco Stolk, present Sanitary and Hydraulic Works Director, under whose sponsorship the laboratory is experiencing a healthy growth.

Corrosion Control by pH Correction

By Irving L. Dahljelm

BECAUSE none of the metals in common use for the fabrication of distribution system pipe and fittings are found in nature in the form in which they are used, there is a constant tendency for those metals to revert to their natural form. The effects of the natural elements—rain, air, carbon dioxide, etc.—on newly fabricated metals which have been exposed to the atmosphere are well known. For the prevention or control of these effects, many industries have sprung up and are doing a thriving business. Their various approaches to the problem depend to a considerable extent upon the theory or hypothesis which they accept as explaining the cause of corrosion, but the fact that so many are thriving on their efforts is a good indication of the seriousness of the problem and the variety of its considerations. A review of the work of the past and present leads to the conclusion that each phase of the problem must be considered individually and that much study and experimentation must be undertaken before any real solution to the problem, as a whole, is found.

In many cases, the rate of corrosion may be such that the problem is not considered to be of economic importance, in which event little or nothing will be done in an attempt to counteract its effects. When leaking hot-water tanks, clogged hot-water lines, excessive tuberculation of pipes and other equipment, and the indiscriminate use of so-called rust-eliminating compounds become the rule rather than the exception, however, the problem should be considered of sufficient economic importance for scientific study and for an attempt to find methods of correction.

At Highland Park the water supplied to consumers has not been considered corrosive. Tuberculation of the distribution system has

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A paper presented on September 12, 1940, at the Michigan Section Meeting, Ann Arbor, Mich., by Irving L. Dahljelm, Filter Plant, Highland Park, Mich.

been so slight that no problem of maintaining flows has been apparent, and failure of cold-water service lines has never been of such magnitude as to require serious consideration. That corrosion was taking place was apparent, however, when the elevated storage tank was drained for painting or when long unused fire hydrants were opened for flushing. In these cases the bottom of the standpipe always contained a considerable quantity of clay-like brownish rust as well as particles of paint which had scaled off the inside surface of the tank, and the water which flowed from the hydrants was always rusty brown in color for a considerable period of time. The condition, although recognized, was not, however, considered to be of sufficient importance to warrant serious consideration until some time after the installation of automatic chlorinators.

Corrosion Investigation

A considerable time after installation of the new chlorinators, it was found that the water-connecting links on the differential converters were fouling and causing difficulties in the proper automatic proportioning of the chlorine dosage. Investigation revealed that products of corrosion were responsible for the fouling and improper operation of the equipment. A survey of the plant revealed that corrosion of sufficient magnitude to cause serious trouble was taking place in other parts of the plant. The cast-iron cylinder heads on the hydraulic filter valves were corroding to an extent where products of corrosion were causing serious scoring of the bronze liners of the hydraulic cylinders, and the supply lines to the hydraulic filter table valves were found to be so badly corroded that the flow of water to the hydraulic cylinders was hardly sufficient to open and close the valves. Further investigation revealed that corrosion was particularly bad in hot-water systems and that many of the larger buildings were experiencing serious trouble in concealed hot-water lines, especially when the water was shut off during repair work. When the water was turned on again after completion of the repairs it was found that fixtures were badly clogged with loosened products of corrosion.

Studies of various analyses of the water as it entered the distribution system indicated that the constituents present which would most likely influence corrosion were: dissolved oxygen, 8.0 to 14.0 p.p.m.; free carbon dioxide, 0.9 to 24.4 p.p.m.; and a pH value ranging from 6.5 to 7.5. The sulfate and chloride contents were not

considered to be sufficiently high to be of significance, being 13.0 and 6.0 p.p.m. respectively.

Application of the calcium carbonate stability test indicated that the water should be corrected to a pH of 8.3 to be in chemical balance; and a determination of the pH_s value indicated that a pH of 8.2 would give a zero saturation index.

Careful consideration was next given to the various chemicals which might be used to accomplish the desired increase in pH value. Such factors as the cost of the chemical, space available for installation of feeding equipment, control of feeding, transportation of the dissolved chemical a distance of 240 ft. to the point of application, and the storage and handling of chemicals, as well as a study of the chemical composition of the water to be treated, all influenced the final decision to use an impure caustic soda, known as caustic bottoms, and containing a guarantee of 87.6 per cent caustic as NaOH.

Chemical Feeding

The chemical is delivered to the warehouse in steel drums, each containing approximately 750 lb. of solid caustic soda. When required for use, the steel drum is cut open and the solid cake of caustic rolled on a dissolving rack. The rack is then placed on a truck and transported to the filter plant where it is hoisted to the second floor, by an electric hoist, and placed on hangers in a dissolving tank. Water is added and the cake of caustic dissolves in 6 to 8 hr., resulting in a solution containing approximately 30 per cent NaOH as determined by titration with 1.25 *N* sulfuric acid. This solution is then diluted to approximately 10 per cent NaOH and flows by gravity through a constant head box to the point of application. A "Micromax" pH recorder-controller serves to control the application of chemical automatically and to give a continuous record of the pH value of the treated water. The operation of the equipment is simple and requires very little attention. After the pH value desired has been determined, it is necessary only to turn a knob on the controller so that an indicator points to the desired value. If this value is different from the actual pH of the water, the potentiometer circuit of the recorder-controller is unbalanced and immediately the controller, operating through a relay detector, actuates a reversible motor drive which changes the feed valve position and increases or decreases the dosage of chemical until the potentiometer circuit is

again in balance and the desired pH value has been obtained. Advantages of this type of chemical feed control are readily seen when it is realized that variations in the chemical strength of solution being fed, as well as changes in the pH value of the water being treated, are both automatically controlled.

Procedure of Treatment

When the treatment was begun, it was decided to increase the pH value gradually from 7.1, as it was on March 8, 1939, the day that treatment began, to a pH of 7.7, at which point it was maintained for seven days. It was then increased to 7.9 for three days; 8.1 for three days; 8.3 for three days; 8.5 for three days; and finally 8.6. On March 29, samples of water were obtained from various points in the distribution system and analyzed to determine whether the chemical composition of the water had changed after it had left the treatment plant. Results showed a significant increase in total solids, iron, calcium, magnesium, sulfates, chlorides, and total hardness; and a decrease in total alkalinity, carbonates, and pH value. The changes would seem to indicate a removal and solution of corrosion products and a deposition of calcium carbonate on the interior of the lines. The plant effluent at that time had a pH value of 8.6, a total alkalinity of 105 p.p.m., and 20 p.p.m. carbonates, in terms of $CaCO_3$.

It was decided to maintain a pH of 8.6 for a period of time to make possible the observation of the effect of the water on scale covering the heating coils of a hot water bath maintained at 65°C. and through which flowed treated water. Shortly, it was noted that the coating on the copper heating coils was breaking up and sloughing off, and that the brass grating, used for supporting laboratory ware in the bath, showed spotty raised white deposits similar to the tubercles which form in water mains. An examination of the metal after removal of the deposits showed that pitting of the metal had begun so it was concluded that dezincification of the brass was taking place.

On April 11, the pH was reduced to 8.3 and on May 3, further reduced to 8.0. The pH value remained at 8.0 to 8.1 until October 14, when the control was set at 7.9 to give a water containing no carbonates in terms of $CaCO_3$ and no free carbon dioxide as determined by *Standard Methods* tests.

Results

It is somewhat early to comment on the action which is occurring. Observations at the present time, however, indicate results which may be of value and which appear to promise benefits other than pH control that will result from the treatment.

An attempt has been made to hold the pH at the control point of pH 7.9, allowing a normal variation from 7.8 to 8.0, as observation

TABLE 1

Typical Analysis of City Tap Water Since pH Control

	p.p.m.
Total solids	120.0
Iron (Fe)	0.05
Silica (SiO_2)	1.6
Al_2O_3 and Fe_2O_3	1.2
Sulfates (SO_4)	14.8
Chlorides (Cl)	5.5
Calcium (Ca)	26.7
Magnesium (Mg)	7.4
*Sodium (Na)	5.4
†Total Hardness	97.1
†Total Alkalinity	85.7
†CO_3 Alkalinity	2.0
†HCO_3 Alkalinity	83.7
†Free CO_2	0
†Non-CO_3 Hardness	11.4
‡pH Value	8.1

* By difference.

† As $CaCO_3$.

‡ pH corrected to 7.9–8.1 using NaOH. Average, 17 months, 7.95.

seems to indicate that both the hot and cold water show the least amount of visible corrosion and the hot water shows the least amount of visible scale deposition at this value. A determination of the Langelier pH_s index on the present plant effluent gives a value of 8.1. This would indicate a saturation index of -0.1 to -0.3 or a slightly corrosive water according to the Langelier index and the calcium carbonate stability test. A typical analysis of city tap water since pH control was initiated is shown in Table 1.

It will probably be some time before there is available definite knowledge of just how valuable the present treatment is from a pH

control point of view. It is known, however, that when, in the latter part of July, the elevated tank was drained for painting, the water in the bottom of the standpipe was clear and there was no indication of the reddish-brown clay-like deposit always present in the past. Information furnished by the Department of Public Works also indicates that there has been a noticeable decrease in the number of old hot-water tanks picked up in the alleys during the past few months. Whether this is significant is questionable, because no definite record of the number of old hot-water tanks picked up is kept.

Other benefits which, it is believed, may be attributed to the new treatment are: a reduction of one-third in the amount of alum necessary to obtain good flocculation; an increase in the length of filter runs; and a considerable saving in the actual amount of wash water used.

TABLE 2

Comparison of the Average Chemical Treatments for 17-Month Periods Before and After pH Control

CHEMICAL	COST PER POUND	AMOUNT OF CHEMICAL USED	
		Before pH Control	After pH Control
		p.p.m.	*p.p.m.*
Activated Carbon	$0.04725	1.77	1.71
Alum	0.0133	10.53	7.05
Caustic Soda	0.0175	none	3.42
Chlorine	0.075	0.29	0.27

As shown in Table 2, the actual total chemical cost of treatment has increased $0.11 per million gallons for the period covered by the use of caustic soda as compared with a like period immediately preceding its use. The saving in wash water alone actually offsets the increased chemical treatment cost, with the result that, in the light of present knowledge, a better product is supplied to the consumer at no additional cost of treatment. It should be emphasized, however, that no claim is made that corrosion is entirely eliminated and that present knowledge of the subject indicates that the pH range between a corrosive water and one which deposits calcium carbonate may be very narrow. Therefore, it may be in order at this time to advise great caution in the use of chemicals acceptable for use in pH correction of potable water supplies.

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Corrosion Experience at Richardton, N. D.

By Lloyd K. Clark

IN 1937, the City of Richardton, N. D., placed in operation a newly completed water and sewerage system. The plans and specifications for the system were prepared by a competent engineer and reviewed and approved by the engineering division of the state department of health. The installation was made through the Public Works Agency. Although no chemical laboratory had yet been set up in the health department, the state university made a chemical analysis of the well water supply to be used in the system in accordance with the requirements of the P.W.A. and the health department. This analysis showed a water which was reasonably satisfactory for the section of the country, although the sulfate content of 295 p.p.m. and the iron content of 0.6 p.p.m. were a little high. No pH determination was made.

The water is obtained from a dug well, about 50 ft. deep, from which two tunnels extend horizontally for a distance of 60 ft. at the same level as the bottom of the well. It was determined, too, that considerable lignite was present in the water-bearing strata.

To all intents and purposes the new system was perfectly satisfactory when it was put into use; and it continued to perform satisfactorily in every respect for the first six months. At the end of this period, some "red water" trouble was reported, especially in the hot-water lines. Later, in February, 1938, the local city health officer requested bacteriological containers in which to submit samples of the city water and asked that a chemical analysis of the supply be made by the State Health Department, but laboratory facilities were not yet available, so it was necessary to refer him to another agency. In the analysis that followed, it was found that

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the bacteriological samples revealed no contamination. This finding, however, was not considered particularly pertinent or reassuring, because it was felt that bacterial content was not a major issue in the corrosion problem which threatened.

Iron in Tap Water

By February, 1939, the iron troubles were becoming worse. At that time, another sample of water was submitted to the health department chemical laboratory which, by then, had finally been provided. The sample, obtained from a city tap, showed an iron content of about 9 p.p.m. and revealed the fact that iron bacteria were present, though not in appreciable quantities.

It was evident from these findings that something was definitely wrong because the iron content of the well water was comparatively low, at least not high enough to cause values of 9 p.p.m. in the tap water. It was therefore suggested that samples of well water and water from the distribution system be submitted so that a determination of the iron content could be made. This analysis showed an iron content of 1.5 p.p.m. in the well water and 20 p.p.m. in the tap water, pH being 6.8.

Because of the varying values of iron content in the well water and the serious corrosion problem apparently due to carbon dioxide gas, the writer went to Richardton to collect additional samples and to investigate the situation—the health department's first experience with corrosion due to the presence of CO_2 in well waters.

Method of Sampling

Samples were again taken from the well by lowering a pail into the water. No additional sample of tap water was taken, because mere observation of the water flushed out of the hydrants was enough to tell that the consumers were getting many times the amounts of iron necessary for proper diet. Towels in barber shops became brick red after one day's use. It was impossible to wash clothes white; and the hot water, in addition to its high iron content, had a very disagreeable odor. It was necessary to flush the city hydrants every day.

Determinations of the CO_2 and iron content of the last group of well water samples obtained showed CO_2 content to be about 90 p.p.m., but results still varied somewhat for both constituents although the samples were taken after the pumps had run for some

time. On the basis of this experience it was suggested that results would probably be more consistent if samples were obtained below the water surface; and that it was, at least, likely that the CO_2 and iron content would be higher because the water obtained from the surface might easily have lost some of the CO_2, and some of the iron in solution might have been oxidized and precipitated.

Samples were then secured, using one of the regular samplers for dissolved oxygen. The first sample was taken at the water surface before pumping was started, and after about 16 hr. had elapsed since the last pumping. Sub-surface samples were then taken at hourly intervals, during pumping for 7 hr. Results, as shown in Table 1, were confirmed by a sales firm, except that their values for Sample 5 showed a CO_2 content of 0.0 and a pH reading of 8.0. Since some

TABLE 1

Results of Analyses of Richardton Well Water at Various Intervals During Pumping

TIME OF SAMPLING	pH	CARBON DIOXIDE		IRON
		as CO_2	as $CaCO_3$	
		p.p.m.	*p.p.m.*	*p.p.m.*
Before starting pumps	6.5	107	243	0.3
1 hr. later	6.5	103	234	0.3
2 hr. later	6.5	107	243	0.2
3 hr. later	6.8	97	220	0.2
5 hr. later		103	234	

time had elapsed between the two analyses, it was decided that the discrepancy was caused by exposure of the sample to the atmosphere. Also, the temperature had been raised considerably.

Installation of Chemical Feeders

With values of 100 p.p.m. CO_2 it was apparent that some immediate steps to check the rapid corrosion in the mains would have to be taken. The health department therefore recommended the immediate installation of two pot-type pressure feeders, one to feed soda ash to raise the pH and the other to add a small quantity of a commercial phosphate stabilizer to prevent precipitation of calcium following the rise in pH. It was realized that about 4 lb. of soda ash per 1,000 gallons would be needed to raise the pH to a point where corrosion would cease and that this would be a rather expensive

treatment, considering that the soda ash briquettes which were used cost $4 per 100 lb. plus the freight charges. It was felt, however, that the expense would be justified for the immediate remedy, until a less expensive method could be developed. The cost of the feeders was, of course, very small.

Knowing neither the output capacity of pot-type feeders nor the rate at which the briquettes dissolved, the city installed a 15-pound

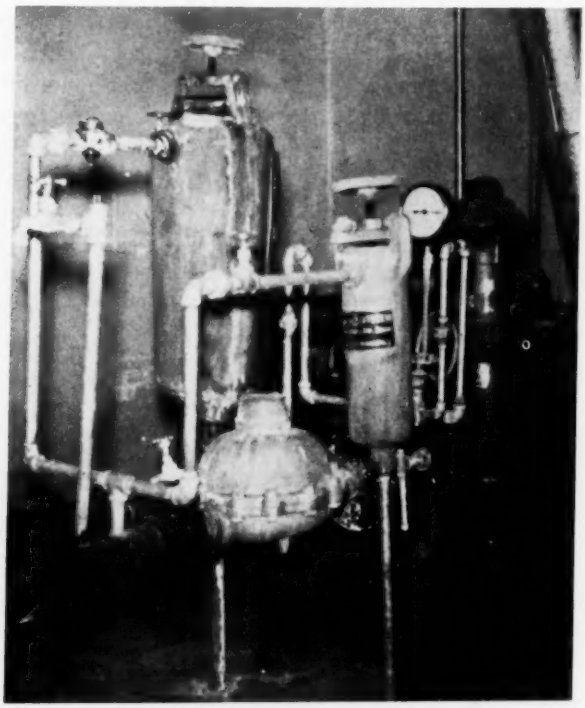

FIG. 1. Arrangement of Take-Off and Solution Lines Leading to Pressure Feeders; showing relative positions of equipment

soda-ash feeder and a small phosphate feeder, using ½-inch feeder lines. They were placed at the pump house on the discharge lines from the two vertical turbine pumps (30-g.p.m. each) which discharged into a common line in the pump house. The take-off lines for the feeders were placed just ahead of the master meter and the solution lines entered just beyond the meter (Fig. 1).

It was soon determined that the arrangement was not satisfactory,

as the pH could not be raised above 7.0. The 15-pound soda-ash feeder was then replaced with a 30-pound feeder, but still the treatment was ineffective. From the experience, it was concluded that too little resistance was being obtained in the meter. A $\frac{3}{4}$-inch orifice plate was then inserted in the 3-inch discharge line with the meter, and when this orifice failed, it was replaced with a $\frac{9}{16}$-inch plate, at the same time cutting the pump discharge to about 8 to 15 g.p.m. This technique seemed to give fairly satisfactory results, but it required the continuous operation of the pumps, so discharge was advanced again and the same results obtained. The maintenance of the results was made possible, of course, by the greater pressure differential which was set up with the increased discharge.

Even this arrangement, however, did not give the desired results. The pH could not be raised higher than about 7.5; corrosion continued, though not nearly so seriously; and the $\frac{1}{2}$-inch feeder lines quite often plugged up with calcium carbonate scale formation. The only alternative was to try a large feeder; so a 45-pound size, using $\frac{3}{4}$-inch feeder lines, was installed; and this, finally, was effective.

With the large feeder, it was possible to obtain pH values as high as 8.5 in the distribution system, and before long the red-water troubles began to subside. Main flushing was soon down to weekly intervals and barbers' towels began to stay white. Two months after the feeder was put into use, the corrosion was apparently completely stopped. No complaints were registered and hydrant flushing was discontinued entirely. Odors were eliminated, though, in part, this may have been due to the 9-inch vent which was inserted in the well cover and extended through the pumphouse roof.

Results of Treatment

From January 3 to February 1, 216,000 gallons of water were pumped, using 800 lb. of soda ash and 10 lb. of phosphate stabilizer. This application represented a rate of feed of 3.7 lb. per thousand gallons for the soda ash and .046 lb. per thousand gallons for the stabilizer, and with it, pH was kept above 8.0, even at full discharge of the pumps. From February 1 to March 8, the rate of feed of the soda ash was lowered to 3 lb. per thousand gallons, but since the pH then dropped to about 7.5 and rust reappeared in the tap water, the rate was again increased to the 4-pound level. (Latest figures (December) from Richardton show a dosage of 3 lb. per 1,000 gal. to maintain satisfactory conditions.)

In this connection, it should also be pointed out that, with the raising of the pH, consumption of water decreased noticeably, due, no doubt, to the elimination of the need for running the water to get a clear supply.

The consumers now seem to be pretty well satisfied, but obviously the city council objects to the present high cost of treatment—about $.20 per thousand gallons. Present water service charges allow 1,500 gal. for the minimum monthly charge of $1.50, and above that are $.20 per thousand gallons. With lawn sprinkling and other summer uses, which increase the consumption about three times the present amounts, in prospect, the council is concerned. The installation of an aerator and receiving reservoir which should dissipate most of the CO_2 is now under consideration. It is planned, however, to retain small feeders to assure continuance of pH control and to feed a small amount of stabilizer.

It should be pointed out, here, that other alkaline chemicals could be used to raise the pH; but lime, for instance, would add to the hardness of an already hard water and would also require more attention in feeding. Other chemicals, such as caustic soda, are not deemed to be any more practicable for this particular installation.

Chemical analysis of the tap water now shows a total alkalinity of about 700 p.p.m., phenolphthalien alkalinity about 30 p.p.m., hardness of about 300 p.p.m., iron content of about 0.5 p.p.m., and a pH of 8.6.

Conclusions

From the experience described here several conclusions may be drawn:

1. Considerable corrosion may be expected from the high free CO_2 content of well waters.

2. CO_2 does not dissipate in appreciable quantities from the surface of the water in a well, even as long as 16 hr. after pumping.

3. Sampling well waters for CO_2 determinations can best be done, if possible, with the use of a sampling device for obtaining water samples for dissolved oxygen determinations.

4. Theoretical dosages of soda ash, in this case, closely approximated actual dosages required to produce satisfactory results.

5. Elimination of corrosion noticeably reduced water consumption.

Corrosion Experience at Orange, Va.

By R. L. Blankenship

THE water supply of Orange, Va., is taken from the Rapidan River which at times yields a very turbid water. Treatment is by rapid sand filtration preceded by stirring in an old style circular basin and coagulation for a 4-hour detention period in a rectangular basin which contains no baffles. The plant was constructed in 1930, and, in 1939, about 200,000 gal. of an ultimate capacity of 1,000,000 gal. were pumped daily.

The supply was known to be corrosive, but the full extent of the corrosivity was not realized until the fall of 1938, when it became necessary to move a newly installed fire hydrant. At that time, it was found that the newly installed 6-inch connection pipe contained tubercles as large as ½ in. in diameter. This, together with continuous customer complaints concerning "red water," prompted the water department to call upon the state health department for assistance in determining the cause of the difficulty. In March, 1939, with the co-operation of the health department, a thorough investigation of the plant and distribution system was undertaken. Findings of the investigators were highly illuminating. Among other things they revealed that:

1. The water in the distribution system was very corrosive, having a low pH value and a carbon dioxide content ranging as high as 11.0 p.p.m.
2. The soda-ash line to the river intake was broken at the river, so that results were being obtained by guess-work only.
3. The 15 min. of relatively poor mixing in the circular stirring basin was inadequate.
4. Additional testing equipment was necessary so that tests on pH and carbon dioxide content could be run.

A paper presented on September 8, 1939, at the Virginia Section Meeting, Charlottesville, Va., by R. L. Blankenship, Town Manager, Orange, Va.

5. Some additional chemical treatment was necessary. (Lime feed was recommended.)

6. Control procedures were inadequate for a close constant check on the system.

7. The dry-feed machines needed re-bushing, new connection pins and re-calibration.

Improvements Effected

Since the investigation came to a head in the middle of a budget year, it was impossible to initiate any wholesale rehabilitation; but it was possible to make many of the improvements recommended. Such changes as were undertaken included:

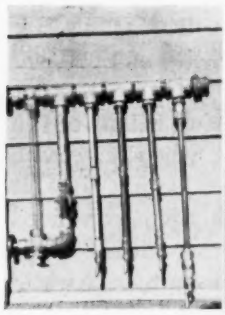

FIG. 1

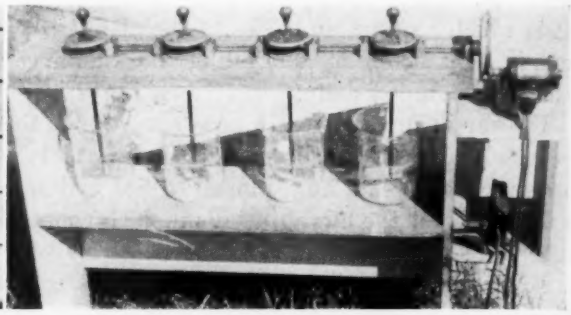

FIG. 2

FIG. 1. Set of ¼-Inch Pipes of Various Materials for Observations on Corrosive Attack of Tap Water
FIG. 2. Stirring Machine

1. The purchase and installation of a lime feeder ($275), and the construction of a home-made solution pot to be used in conjunction with the feeder. With installation of the feeder, the practice of mixing carbon and alum by hand was given up in favor of feeding dustless black alum by the machine.

2. The purchase of a comparator and all the necessary glassware for determining pH. With the aid of six small breast drills (@ $.60 each), a sewing machine motor ($10), some babbit and small brass rods, a stirring machine (Fig. 2), that has functioned very satisfactorily, was constructed. Using this stirrer and a convenient work table and storage cabinet, built at a local shop, the practice of making daily pH determinations was inaugurated.

3. The replacement of all connection pins and bushings on the dry-feed machines, and recalibration of the control equipment.

4. A set of $\frac{1}{4}$-inch pipes (Fig. 1), including black, galvanized and brass pipe, copper tubing and a glass water tube, was made up and installed in the town office to show the actual attacking effect of the water in the distribution system. The pipes are equipped with small petcocks, set to allow a constant flow of water. The pipes are flushed monthly into jars, from which the effect of the water on the different materials may be observed. The suggestion of C. R. Cox (of feeding less lime in summer than in winter and of increasing the amount progressively to reach the middle curve on his chart*) was followed. More chemicals than should be necessary are being used because of the poor arrangements for mixing which still aggravate the corrosive condition.

5. Provision in the budget was made for a vertical stirring device to be installed in the circular mixing chamber and for a slow-moving paddle to be installed in a 9 x 9-foot concrete flume along the side of the filter house and coagulation basin. [Plant improvements, including slow mix and additional settling facilities, are now (1941) under construction.]

6. The materials for a continuous stability indicator were assembled though the actual construction was postponed.

The results of these various efforts toward the alleviation of the corrosion troubles were found to be very gratifying. They made it possible to produce a crystal clear product under the heaviest demands in plant history; and with the installation of additional storage and settling facilities, it is expected that the combination of facilities will result in a first-class plant.

* Cox, Charles R. *Water Purification for the Practical Man.* Case-Sheperd-Mann, New York (1938), pp. 70–74.

Corrosion and Cathodic Protection

By G. H. Montillon

TO APPRECIATE the various factors involved in the cathodic protection of tanks and underground structures it is necessary to understand the nature and mechanism of the corrosion that makes such protection necessary. F. N. Speller, in his book on corrosion (1), offers the following statements on the subject:

"Corrosion of metals may be defined broadly as the chemical action of their environment, often resulting in their deterioration or destruction. It occurs because in many environments, most metals are not inherently stable and tend to revert to some more stable combination, of which the metallic ores, as found in nature, are familiar examples.

"Recent work on the fundamentals of corrosion has shown that the essential phenomena are the same for all metals and alloys, differing only in degree but not in kind.

"It may now be regarded as established that in substantially all cases of corrosion at ordinary temperatures—and these comprise the most important practical cases—the driving force of the corrosion reaction between metal and environment is electrochemical. The magnitude of this electrochemical potential, which varies with the environment and the metal, determines the *tendency* of the reaction to proceed, whereas the *rate* of corrosion is determined mainly by the resistance to the continued progress of the reaction set up by certain of the corrosion by-products."

McKay and Worthington, in their book on the corrosion resistance of metals and alloys (2, p. 33) indicate a series of metals and alloys showing the tendency to corrode, as follows:

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Corroded end (anodic)	Nickel
Magnesium	Brasses
Aluminum	Bronzes
Duralumin	Nickel-copper alloys
Zinc	Copper
Cadmium	Chromium-iron (passive)
Iron	Chromium-nickel-iron (passive)
Chromium iron (active)	Silver solder
Chromium-nickel-iron (active)	Silver
Soft Solder	Gold
Tin	Platinum
Lead	Protected end (cathodic)

This series is built upon actual experience with corrosion and its laboratory measurement. Metals grouped together have no strong tendency to produce galvanic corrosion on each other; connecting two metals, distant from each other on the list, tends to corrode the one higher in the list. Voltage figures are not given because these vary with every new corrosive condition. Relative positions of metals change in many cases, but it is unusual for changes to occur across the spaces left blank. The chromium-irons and chromium-nickel-irons change position, as indicated, depending on oxidizing conditions, acidity and chloride in solution. The series, as it stands, is correct for many common dilute water solutions, such as sea water, weak acids and alkalies.

In the series, a metal high in the list, like zinc, connected to one low in the series, like copper, will, in the presence of a dissolved salt, produce a voltaic cell, with corrosion of the zinc.

A Daniell cell will function according to the reaction

$$Zn + CuSO_4 + H_2O \rightarrow ZnSO_4 + Cu.$$

In this cell, zinc corrodes and copper metal is deposited. In a similar way, in the dry cell, with the elements zinc and carbon,

$$Zn + 2\ NH_4Cl + 2\ MnO_2 \rightarrow Zn(NH_3)_2Cl_2 + Mn_2O_3 + H_2O.$$

In this cell, zinc corrodes and the manganese dioxide acts as a depolarizer.

Many similar voltaic cells may also be indicated, as follows:

1. Two dissimilar metals plus a water solution of a salt or electrolyte.

2. Two dissimilar metals plus two different electrolytes.

3. Two electrodes of the same metal in an electrolyte of different concentrations, *e.g.*, Fe + dilute $MgSO_4$, and Fe + concentrated $MgSO_4$. This is a "concentration cell"; the iron in the dilute solution dissolves.

4. Two electrodes with the same metal and the same electrolyte, but with oxygen bubbling around one iron electrode, *i.e.*, Fe + dilute $MgSO_4$, and Fe with O_2 in solution and bubbling around it. The iron not in contact with the oxygen dissolves.

5. If metal is strained, it is anodic to the unstrained portion, *i.e.*, Fe (strained) + dilute $MgSO_4$, and Fe (annealed, unstrained). The strained iron will dissolve.

6. In a similar way, if an electrolyte is heated or moving, or both, the portion in contact with such electrolyte will corrode, *i.e.*, Fe dissolves in heated moving dilute $MgSO_4$ while Fe in stagnant cold dilute $MgSO_4$ tends not to dissolve.

In natural waters, then, iron will tend to corrode when it is subjected to any of the conditions just noted. The following reactions may occur:

$$Fe + 2\,H_2O \rightarrow Fe(OH)_2 + 2H$$

(metal + water → ferrous hydrate + hydrogen atoms)

This is followed by depolarization by oxygen:

$$2H + \tfrac{1}{2}\,O_2 \rightarrow H_2O$$

(hydrogen atoms + dissolved O_2 → water)

and

$$2H \rightleftharpoons H_2$$

(hydrogen atoms → molecular H_2 or gaseous H_2)

It is evident that rates of corrosion can be varied widely by changes in oxygen concentration and by changes in acidity, for an acid in water produces hydrogen ions.

Under ordinary conditions in natural waters we may have:

1. Dissolved salts leached from the soil constituents, as bicarbonates, sulfates, chlorides and nitrates of calcium, magnesium and iron, as well as small amounts of sodium and potassium.

2. Dissolved oxygen from the air.

3. Weak acids, such as carbonic and sulfurous, or hydrogen sulfide, as in brine wells.

It is a matter of observation, based on these facts, that corrosion of iron will increase as:

1. Acidity of the solution with which it is in contact increases.
2. The available O_2 dissolved in the solution increases.
3. The temperature and rate of movement of the electrolyte in given areas increases.
4. The conductivity of electrolyte in contact with it increases.

In a tank or pipe line, it is necessary to overcome these corrosive conditions by one means or another. Some of these possible ways to minimize corrosion are as follows:

1. Avoiding contact between dissimilar metals.
2. Avoiding the presence of "strained" portions of metal, by annealing.
3. Removal of all dissolved gases, especially oxygen, from the water.
4. Minimizing the necessity for heating moving electrolyte in contact with cold stagnant electrolyte.
5. Deliberate addition of corrosion inhibitors to the water for the formation of a protective film. This may be done by first reducing the acidity with sodium silicate and then adding a chemical, such as the inorganic sodium chromate or dichromate, or the organic aliphatic or aromatic amines, which will produce "passivity."
6. Use of cathodic protection.

The last of these methods of corrosion control, cathodic electrolytic protection, is the one at which this discussion is particularly directed. On this subject, Speller (1, p. 456 ff.) has given a good summary of the generalizations, as follows:

"Electrolytic action accelerates the solution of the metal at the anode and retards it at the cathode. At the same time, if the e.m.f. is over a certain minimum, molecular hydrogen is formed at the cathode and a small amount of oxygen at the anode. The electrolysis of water also produces an alkaline layer at the cathode which may retard corrosion, in the case of iron, by causing the formation of protective coatings; but may increase the action locally in the case of brass tubes. This condition is most marked in waters carrying bicarbonate of lime or other material capable of forming such a protective coating.

"Electrolytic protection of iron may be obtained by contact with a slab of zinc when the water is sufficiently conductive, or by imposing an external e.m.f. on the surface to be protected.

"The deterioration of tubes in condensers and boilers can sometimes be prevented in a more positive manner by the proper application of a sufficient e.m.f. against the surface to be protected. This principle was first applied by Cumberland (3). A potential (usually 6 to 10 volts) sufficient to cause a current of about 2 milliamperes per square foot of cathode surface is passed from submerged and insulated cast-iron anodes to the surface of the tubes.

"Cathodic protection (or forced drainage) may be applied effectively to pipe and electrical cables underground under certain conditions, as has been done elsewhere to metal in water, by keeping the metal to be protected at a lower potential than the surrounding environment. For the effective and economical protection of pipe by this means it is essential that the different sections of the system to be protected, be connected by low-resistant joints; and the pipe should be thoroughly coated with an impervious material of high electrical resistance that can be applied with few discontinuities. This means is used to protect the underground gas-main distributing system in the saline soil of New Orleans (4). Where there is no other difference of potential between the pipe and earth, $\frac{1}{4}$-volt potential impresses on the pipe from some external source have been found sufficient to prevent ordinary corrosion in soil.

"Pipes may be protected from stray-current electrolysis by thorough insulation from the ground, wherever they pass under electric railroad tracks, by using a sufficient number of reliable, insulating joints, by shielding the metal with an external metallic conductor, or by the use of sufficient electrical return drainage to keep the currents off the pipe line."

Review of a few of the articles in the literature of the field will give a more specific picture of the practical applications of this method. Loreaux (5) pointed out the difficulty of keeping tank interiors and filter wash troughs painted and indicated that an annual cost of \$0.03 per sq. ft. was necessary to proper upkeep. He then proceeded to outline the benefits, in terms of cost, that accrued from the installation of cathodic protection. Installation on a 50,000-gallon tank cost only \$250 complete and current cost was \$1.80 per month at \$0.05 per kw. hr. at the outset; and during the eight months of operation, before presentation of the paper, as the coating (apparently $CaCO_3$) deposited on the steel surface, this cost dropped, with the gradual reduction of current used, from 2.3 kw.hr. to 1.2 kw.hr.

From his experience and from the discussion that followed presentation of the paper, Loreaux brought out several conclusions on the subject, as follows:

1. Current consumption should vary in proportion to the metal surface exposed, depending on conductivity (due to mineral content of the water) and length of travel from the suspended electrode to the tank surface.

2. Cathodic protection would cost but little in current consumption if the original protective coating failed in only a few spots, which would be healed quickly and with minor current consumption, precluding the further spread of corrosion under the coating as is usual. Therefore, there is a balance between cost of painting or coating and cost of cathodic protection which would preclude the need for further coating below the water line. The problem zone would be that above the mean water line and because of this it is, of course, valuable to most effective protection to maintain as nearly as possible a constant water level.

3. As the calcium plating progresses, the rate of build-up apparently diminishes, eventually giving complete insulation and stopping further deposition automatically.

In a paper published in November, 1938 (6), Hess described what was then a new method of tank protection. He gave the cost of cathodic protection of a 200,000-gallon tank, in service for nine years, as being $0.40 per month with power at $0.02 per kw.hr. Equipment cost was $325.00. One anode of stainless steel, $1\frac{1}{4}$ in. in diameter, was used in the center of the tank.

Finally, some idea of the possible types of electrical equipment for supplying current for cathodic protection of tanks may be obtained from the literature on protection of oil, gas and water pipe lines. In an article published in November, 1939 (7), Scherer presented a great deal of data on this subject. Among other things, he pointed out that a group of 26 companies included in his survey were using 542 electric power units for the cathodic protection of 2,006 mi. of pipe. This large number of power units was divided among rectifiers (151, or 27.9 per cent), motor generator sets (68, or 12.5 per cent), windmill generators (228, or 42.1 per cent), and gas-engine power units (95, or 17.5 per cent).

Scherer also emphasized the fact that the choice of electrical equipment depends on local economic conditions, but that it should be remembered that rectifiers of the copper oxide or copper sulfide

type have no mechanical moving parts and require no oiling or other attention except inspection and current adjustment.

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Metal Protective Finishes

By J. A. Meacham

THE theoretical causes for the corrosion of iron have been discussed in detail by many authorities. All agree that complete protection would be afforded if a thoroughly waterproof coating of paint could be applied. No paint coating, however, is completely impervious to moisture, which is the basic cause of all corrosion. Furthermore, the usual thickness being not over $\frac{1}{200}$ inch, the paint film is likely to be broken in service. For this reason, the initial coat of paint in contact with the metal must contain chemically active pigments which will retard or inhibit corrosion even though the film permits moisture to pass through.

Red lead, lead chromate, zinc chromate and blue lead pigments have proved, through years of research and service, that they do retard and inhibit corrosion. Therefore, as a preliminary step, every metal surface should be coated with an inhibitive primer of this type.

The finish coats, when applied over a suitable primer, serve as a protective coating for the primer and to provide the desired color. Finish coats, therefore, must be essentially resistant to the destructive influence of weather, sunlight and such fumes as may be present.

Great improvements have been made in paint vehicles in recent years through the use of synthetic resins. They have greatly increased water resistance, hastened drying, made harder and tougher finishes, and have materially improved the appearance of outside paints by enabling them to retain their gloss for longer periods of time.

Synthetic vehicles are used on metal surfaces both in primers and finish coats. They are used for normal outdoor or indoor ex-

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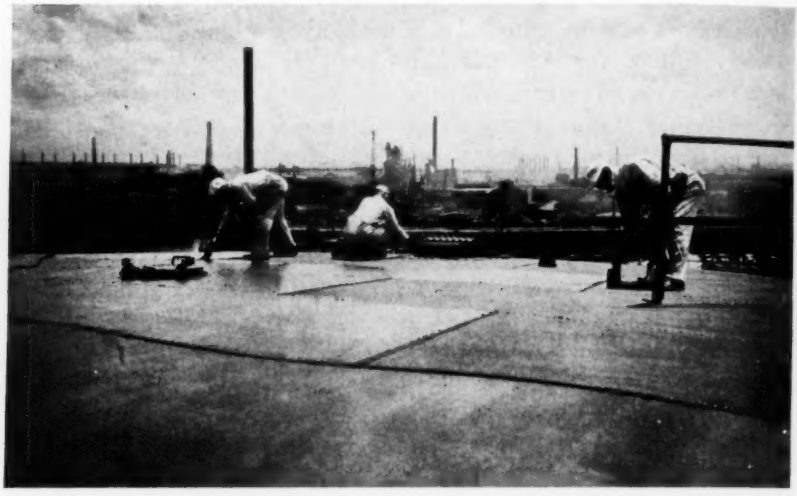
posures, as well as for severe fume conditions. They are not widely used, however, on wood surfaces.

In general, alkyd synthetic finishes are selected for best performance out of doors on metal, since they have the ability to retain their gloss under sunlight and have outstanding weather durability; and phenolic synthetic vehicles are selected for maximum resistance to acids, alkalis, and moisture. The desired pigment combinations may be used in both types of synthetic vehicles.

It can be demonstrated that the ability of a paint film to resist the passage of water is in direct proportion to the film thickness.



Dome of Tank; showing application of finish which will be required to protect metal from the effects of exposure

More and more we are coming to believe that a greater total thickness of paint increases the protection afforded. For this reason, the application characteristics of a paint are important. It must apply readily so the operator can produce a full, uniform coat on all parts of the structure. If the paint pulls unduly, the result is uneven distribution with too much paint on one part of the surface; too little on another. If the paint is too thin, it flows out into a thin film which does not give the required protection. If it dries too slowly, the film may be injured in handling.

With paints of proper consistency, as many as four coats—usually

two priming coats and two finishing coats—are now being recommended for new work on important structures. One priming coat is applied in the shop; a second coat of primer is applied in the field, after erection. This covers any skips in the first shop coat or abrasions caused in transit. The two additional finish coats then afford the necessary protection for the primers. Of course, good protection can be achieved with three-coat work, that is, one primer and two field coats.

Aluminum paint is used extensively for metal protection and with properly selected vehicles gives good results. The individual flakes of aluminum over-lap in horizontal layers and the distance that moisture must travel from the outer surface to reach the steel is materially increased as the moisture must follow a devious and, therefore, longer path around the ends of the flakes. This, in effect, increases the net thickness of the film, and thereby, it is claimed, the ability of aluminum paint to exclude moisture.

Preparation of Surfaces

No phase of metal protection with paint is more important than surface preparation. This is true for new steel as well as for repainting work. It is essential that rust, mill scale, and foreign material be removed before the paint is applied.

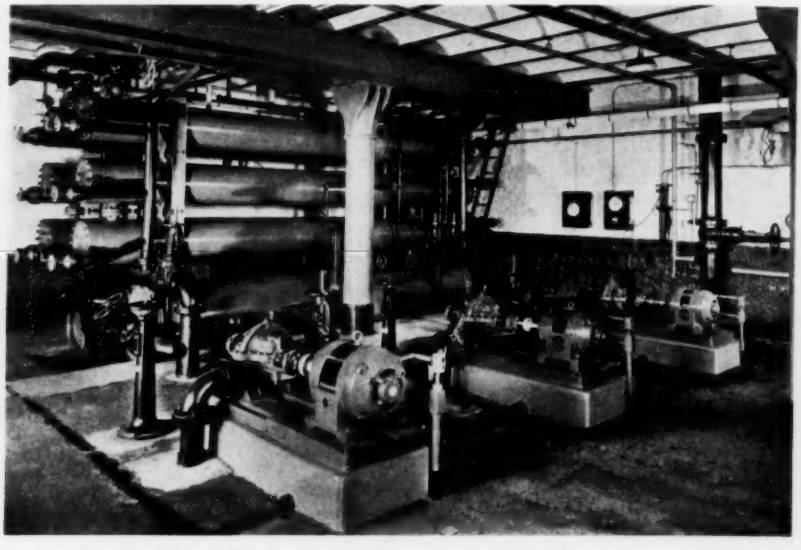
Mill scale is an oxide of iron, formed on the surface in the process of rolling. If the mill scale were a continuous film, firmly adherent at all points, it would of itself be an excellent protection against further oxidation and would not have to be removed. But mill scale is not continuous and there are numerous weak spots which permit moisture to enter. Rusting takes place under the scale, eventually forcing off both the scale itself and the paint, which is applied over it. For this reason, good practice requires complete removal of all mill scale, or, at least, that which is not tightly adherent to the metal.

Various methods are employed for cleaning steel, including pickling, sand-blasting, wire brushing, weathering, chemical treatment and flame cleaning. Pickling, of course, is hardly practicable for structural steel work so need not be considered.

Sand blasting is an effective means of removing mill scale and rust but, according to some authorities, it has the disadvantage of making the exposed steel, after blasting, highly reactive and, therefore, likely to corrode very rapidly. A sand-blasted surface must be covered with paint immediately.

Wire brushing, by hand- or power-driven brushes, will remove loose scale. If the work is well done, this is a satisfactory means of preparing steel for painting. The tightly bound scale, which is not removed by brushing, is not considered detrimental to paint adhesion. Careless brush work is, however, of very little benefit and the closest inspection of the operation is necessary.

Weathering, *i.e.* leaving the steel exposed for considerable periods of time, will remove the scale but, in the meantime, the steel acquires a coat of red rust. According to results of tests by the American



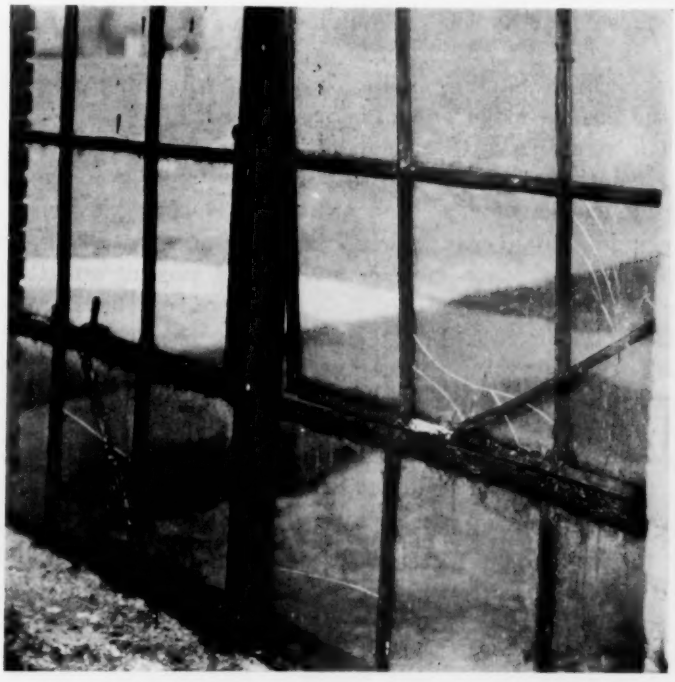
Interior Mechanical Equipment; showing appearance of plant adequately protected with metal protective finishes

Society for Testing Materials, panels treated in this way show more rapid corrosion after painting than panels which are painted without being weathered first.

Chemical treatments are made with proprietary compounds, containing phosphoric acid, which convert the steel surface into a deposit of iron phosphate. This destroys existing rust and "passifies" the surface so that further rust does not form easily. Under closely controlled conditions, as for example in a shop, on a manufactured product, this method is highly effective. For structural steel work, however, the practical difficulties have not been over-

come entirely. It is easy for excessive quantities of the phosphoric acid to accumulate in pools and crevices; and the application of paint over such areas is dangerous.

Flame cleaning is a very recent development. Small, brush-like flames are moved over the surface and, it is claimed, the heat drives out moisture and loosens mill scale. This method has not been widely tested as yet but offers excellent possibilities.



Unprotected Metal Window of a Sewage Disposal Plant; showing rust and broken panes of glass resulting from the corrosion caused by condensation from nearby filter units

For preparing a previously painted steel structure which has been badly neglected, with the steel heavily corroded, it is suggested that sand blasting would be the best practical solution.

Utility Finishes

The question of finishing machinery and equipment on the interior of the plant merits a brief discussion. As these are metal surfaces, the principle of using an inhibitive type of primer, such as

lead or zinc chromate, on all bare metal is important. The development of synthetic enamels has made it possible to obtain beautiful finishes in a wide selection of colors which are ideal for machinery and equipment. They have fine covering ability, will dry quickly, flow into a smooth gloss or egg-shell finish, as desired, and are highly durable. Special synthetic enamels of the phenolic type are available where chlorine and other chemical fumes create exceptionally severe conditions.

The finishing of a piece of equipment to give a superior appearance is, in good part, a matter of skill on the part of the mechanic doing the work. Sanding, filling, sealing and finishing are required when the surface is uneven and badly chipped.

Certain metal surfaces are largely hidden from view and do not require painting for decoration. It has been found that economical protection can be afforded such surfaces by applying low cost bituminous paints, frequently without the use of primers. These paints are black or very dark in color and do not present an attractive appearance but, in many cases, their use affords excellent protection at reasonably low cost.

Much experimental work has been carried out in the field of metal protection and much progress has grown out of this work, but many problems still remain to be solved, particularly regarding the use of rust-inhibitive chromate pigments for priming coats, the development of improved synthetic finishes, the determination of adequate film thicknesses and the proper preparation of surfaces before the application of protective finishes. Future progress must depend on the measure of success with which these and similar problems are met.

The New River Decision

Supreme Court of the United States

No. 12.—October Term, 1940.

The United States of America, Petitioner, *vs.* Appalachian Electric Power Company.	On Writ of Certiorari to the United States Circuit Court of Appeals for the Fourth Circuit.

[December 16, 1940.]

Opinion of the Court

Mr. Justice Reed delivered the opinion of the Court.

This case involves the scope of the federal commerce power in relation to conditions in licenses, required by the Federal Power Commission, for the construction of hydroelectric dams in navigable rivers of the United States. To reach this issue requires, preliminarily, a decision as to the navigability of the New River, a watercourse flowing through Virginia and West Virginia. The district court and the circuit court of appeals have both held that the New River is not navigable, and that the United States cannot enjoin the respondent from constructing and putting into operation a hydroelectric dam situated in the river just above Radford, Virginia.

Sections 9 and 10 of the Rivers and Harbors Act of 1899 make it unlawful to construct a dam in any navigable water of the United States without the consent of Congress.[1] By the Federal Water Power Act of 1920,[2] however, Congress created a Federal Power

See Editorial Note on page 342.

[1] 30 Stat. 1151, 33 U. S. C. §§401, 403.

[2] 41 Stat. 1063. The Act was amended by 49 Stat. 838 (1935), U. S. C. Supp. V, Title 16, §791 *et seq.*, by which it became known as the Federal Power Act.

Commission with authority to license the construction of such dams upon specified conditions. Section 23 of that Act provided that persons intending to construct a dam in a non-navigable stream may file a declaration of intention with the Commission. If after investigation the Commission finds that the interests of interstate or foreign commerce will not be affected, permission shall be granted for the construction. Otherwise construction cannot go forward without a license.

The Radford Dam project was initiated by respondent's predecessor, the New River Development Company, which filed its declaration of intention with the Federal Power Commission on June 25, 1925. The Commission requested a report from General Harry Taylor, then Chief of Engineers of the War Department. He first reported that the river was navigable, and also that while the water flow from the dam, if not properly regulated, could have an adverse effect on navigation during low water stages in the Kanawha River (of which the New was one of the principal tributaries), such possible adverse effect would not warrant refusing a license to construct the dam if control was maintained by the United States. On review at the Commission's request, however, General Taylor rendered a second report, concluding that the New River in its present condition was not navigable and that navigation on the Kanawha would not be adversely affected by the proposed power development. On March 2, 1926, the Commission held a hearing on the declaration; the only evidence then submitted was General Taylor's second report.

Respondent, the Appalachian Electric Power Company, took an assignment of the declaration of intention on August 30, 1926, and several days later filed an application for a license on the Commission's suggestion that this would expedite matters and could be withdrawn if it later developed that no federal license was required. In October, the district engineer of the War Department held a public hearing at Radford. On June 1, 1927, the Commission made a finding that the New River was not "navigable waters" within the definition in section 3 (8) of the Federal Water Power Act of 1920 but that (under section 23 of the Act) the project would affect the interests of interstate and foreign commerce. On July 1, 1927, the Commission tendered to respondent a standard form license which the respondent refused in April, 1928, principally on the ground that the conditions—especially those concerning rates, accounts and eventual acquisition—were unrelated to navigation. In February, 1930, respondent reiterated that its project was not within the Commis-

sion's jurisdiction, but nevertheless offered to accept a "minor-part" license[3] containing only such conditions as would protect the interests of the United States in navigation. In September, 1930, Attorney General Mitchell advised the Commission that it could properly issue such a minor-part license;[4] the question submitted by the Commission had stated that the New River was neither navigated nor navigable in fact. On November 25, the Commission "declined to take action on the application favorable or adverse," on the ground that a court adjudication was desirable. After the establishment of the Commission as an independent agency,[5] it held another hearing in February, 1931; in April it denied the application for a minor-part license, directed that the respondent be tendered a standard form license under the Act, and ordered it not to proceed without such a license. A minority of the Commission then favored a finding that the New River was navigable; the majority, however, thought that question was for the courts and that the Commission's jurisdiction was properly based upon section 23 of the Federal Water Power Act.

On June 8, 1931, the respondent brought an action against the Commission to remove a cloud on its title and to restrain interference with the use of its property. This case was dismissed for jurisdictional reasons.[6] While it was pending, on October 12, 1932, the Commission without notice adopted a resolution that the New River, from the mouth of Wilson Creek, Virginia, north, was navigable.

The respondent began construction work on the dam about June 1, 1934. On May 6, 1935, the United States filed this bill for an injunction against the construction or maintenance of the proposed dam otherwise than under a license from the Federal Power Commission, and in the alternative a mandatory order of removal. It alleged that the New River is navigable; that the dam would constitute an obstruction to navigation and would impair the navigable capacity of the navigable waters of the United States on the New, Kanawha and Ohio Rivers; that the Commission had found the dam would affect the interests of interstate or foreign commerce; and

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[3] Section 10(i).

[4] 36 Op. A. G. 355.

[5] Originally it consisted of three cabinet officers, ex officio: the Secretaries of War, Interior, and Agriculture. By 46 Stat. 797 it was reorganized into an independent Commission with five members. The new Commission began to function on December 22, 1930.

[6] Appalachian Electric Power Co. *v.* Smith, 67 F. (2d) 451, cert. denied, 291 U. S. 674.

that its construction therefore violated both the Rivers and Harbors Act and the Federal Water Power Act. Respondent denied these allegations, and also set forth a number of separate defenses based on the assumption that the New River was non-navigable. The fortieth and forty-first paragraphs of the answer, however, set forth defenses relied on by the respondent even if the river were held navigable. The substance of these was (1) that the conditions of any federal license must be strictly limited to the protection of the navigable capacity of the waters of the United States; and (2) that the Commission's refusal to grant the minor-part license containing only such conditions was unlawful, and that any relief should be conditioned upon the Commission's granting respondent such a license. By these defenses respondent put in question—in the event of an adverse holding on navigability—the validity of the conditions of the Act carried over into the standard form license which relate to accounts, control of operation and eventual acquisition of the project at the expiration of the license.

After trial, in an opinion reinforced by formal findings of fact and law, the district court decided that the New River is not a navigable water of the United States; that respondent's dam would not obstruct the navigable capacity of the Kanawha or any other navigable river, and would not affect the interests of interstate commerce; that the Power Commission's findings on these matters were not final but subject to the determination of the courts;[7] that the Federal Water Power Act did not vest in the Commission authority to require a license in a non-navigable river; that even if the Commission had authority to require some license for a dam in non-navigable waters, it could not impose conditions having no relation to the protection of the navigable capacity of waters of the United States; and that its effort to impose upon respondent a license containing unlawful conditions barred the United States from relief. The district judge therefore dismissed the bill, but left it open to the Government to assert its rights if future operation of the project interfered with the navigable capacity of the waters of the United States. The circuit court of appeals, with one judge dissenting, affirmed. We granted certiorari.[8]

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[7] In both courts below the Government unsuccessfully urged that the findings of the Commission, if supported by substantial evidence, were conclusive. Although it still regards this contention as correct, the Government does not seek to have this Court pass on it in this case.

[8] 309 U. S. 646.

Concurrent Findings. The district court's finding that the New River was not navigable was concurred in by the circuit court of appeals after a careful appraisal of the evidence in the record.[9] Both courts stated in detail the circumstantial facts relating to the use of the river and its physical characteristics, such as volume of water, swiftness and obstructions. There is no real disagreement between the parties here concerning these physical and historical evidentiary facts. But there are sharp divergencies of view as to their reliability as indicia of navigability and the weight which should be attributed to them. The disagreement is over the ultimate conclusion upon navigability to be drawn from this uncontroverted evidence.

The respondent relies upon this Court's statement that "each determination as to navigability must stand on its own facts,"[10] and upon the conventional rule that factual findings concurred in by two courts will be accepted by this Court unless clear error is shown.[11]

In cases involving the navigability of water courses, this Court, without expressly passing on the finality of the findings, on some occasions has entered into consideration of the facts found by two courts to determine for itself whether the courts have correctly applied to the facts found the proper legal tests.[12] When we deal with issues such as these before us, facts and their constitutional significance are too closely connected to make the two-court rule a serviceable guide. The legal concept of navigability embraces both public and private interests. It is not to be determined by a formula which fits every type of stream under all circumstances and at all times. Our past decisions have taken due account of the changes and complexities in the circumstances of a river. We do not purport now to lay down any single definitive test. We draw from the prior decisions in this field and apply them, with due regard to the dynamic nature of the problem, to the particular circumstances presented by the New River. To these circumstances certain judicial standards are to be applied for determining whether the complex of the conditions in respect to its capacity for use in interstate commerce render it a

[9] 107 F. (2d) 769, 780, 787.

[10] United States *v.* Utah, 283 U. S. 64, 87.

[11] Brewer Oil Co. *v.* United States, 260 U. S. 77, 86; e.g., Alabama Power Co. *v.* Ickes, 302 U. S. 464, 477; Pick Mfg. Co. *v.* General Motors Corp., 299 U. S. 3; Texas & N. O. R. Co. *v.* Ry. Clerks, 281 U. S. 548, 558; United States *v.* O'Donnell, 303 U. S. 501, 508.

[12] United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 699; Leovy *v.* United States, 177 U. S. 621; Economy Light Co. *v.* United States, 256 U. S. 113, 117; United States *v.* Holt Bank, 270 U. S. 49, 55.

navigable stream within the Constitutional requirements. Both the standards and the ultimate conclusion involve questions of law inseparable from the particular facts to which they are applied.

Navigability. The power of the United States over its waters which are capable of use as interstate highways arises from the commerce clause of the Constitution. "The Congress shall have Power . . . To regulate Commerce . . . among the several States." It was held early in our history that the power to regulate commerce necessarily included power over navigation.[13] To make its control effective the Congress may keep the "navigable waters of the United States" open and free and provide by sanctions against any interference with the country's water assets.[14] It may legislate to forbid or license dams in the waters;[15] its power over improvements for navigation in rivers is "absolute."[16]

The states possess control of the waters within their borders, "subject to the acknowledged jurisdiction of the United States under the Constitution in regard to commerce and the navigation of the waters of rivers."[17] It is this subordinate local control that, even as to navigable rivers, creates between the respective governments a contrariety of interests relating to the regulation and protection of waters through licenses, the operation of structures and the acquisition of projects at the end of the license term. But there is no doubt that the United States possesses the power to control the erection of structures in navigable waters.

The navigability of the New River is, of course, a factual question[18] but to call it a fact cannot obscure the diverse elements that enter into the application of the legal tests as to navigability. We are dealing here with the sovereign powers of the Union, the Nation's right that its waterways be utilized for the interests of the commerce of the whole country. It is obvious that the uses to which the streams may be put vary from the carriage of ocean liners to the

[13] Gibbons *v.* Ogden, 9 Wheat. 1, 189; Leovy *v.* United States, 177 U. S. 621, 632.

[14] Gilman *v.* Philadelphia, 3 Wall. 713, 724-25; United States *v.* Coombs, 12 Pet. 72, 78.

[15] Willson *v.* The Black Bird Creek Marsh Co., 2 Pet. 245, 250; United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 703.

[16] United States *v.* River Rouge Co., 269 U. S. 411, 419.

[17] Water Power Co. *v.* Water Commissioners, 168 U. S. 349, 366; United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 702.

[18] Arizona *v.* California, 283 U. S. 423, 452.

floating out of logs;[19] that the density of traffic varies equally widely from the busy harbors of the seacoast to the sparsely settled regions of the Western mountains.[20] The tests as to navigability must take these variations into consideration.

Both lower courts based their investigation primarily upon the generally accepted definition of *The Daniel Ball*.[21] In so doing they were in accord with the rulings of this Court on the basic concept of navigability.[22] Each application of this test, however, is apt to uncover variations and refinements which require further elaboration.

In the lower courts and here, the Government urges that the phrase "susceptible of being used, in their ordinary condition," in the *Daniel Ball* definition, should not be construed as eliminating the possibility of determining navigability in the light of the effect of reasonable improvements. The district court thought the argument inapplicable.[23]

The circuit court of appeals said:

"If this stretch of the river was not navigable in fact in its unimproved condition, it is not to be considered navigable merely because it might have been made navigable by improvements which were not in fact made. Of course if the improvements had been made the question of fact might have been different."[24]

[19] The Montello, 20 Wall. 430, 441.

[20] United States *v.* Utah, 283 U. S. 64, 83.

[21] 10 Wall. 557, 563:

". . .Those rivers must be regarded as public navigable rivers in law which are navigable in fact. And they are navigable in fact when they are used, or are susceptible of being used, in their ordinary condition, as highways for commerce, over which trade and travel are or may be conducted in the customary modes of trade and travel on water. And they constitute navigable waters of the United States within the meaning of the acts of Congress, in contradistinction from the navigable waters of the States, when they form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other States or foreign countries in the customary modes in which such commerce is conducted by water."

United States *v.* Appalachian Electric Power Co., 23 F. Supp. 83, 98; same, 107 F. (2d) 769, 780.

[22] United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 698; Brewer Oil Co. *v.* United States, 260 U. S. 77, 86; United States *v.* Holt Bank, 270 U. S. 49, 56; United States *v.* Utah, 283 U. S. 64, 76; United States *v.* Oregon, 295 U. S. 1, 15.

[23] 23 F. Supp. at 99–100.

[24] 107 F. (2d) at 786.

To appraise the evidence of navigability on the natural condition only of the waterway is erroneous. Its availability for navigation must also be considered. "Natural and ordinary condition"[25] refers to volume of water, the gradients and the regularity of the flow. A waterway, otherwise suitable for navigation, is not barred from that classification merely because artificial aids must make the highway suitable for use before commercial navigation may be undertaken. Congress has recognized this in section 3 (8) of the Water Power Act by defining "navigable waters" as those "which either in their natural or improved condition" are used or suitable for use. The district court is quite right in saying there are obvious limits to such improvements as affecting navigability. These limits are necessarily a matter of degree.[26] There must be a balance between cost and need at a time when the improvement would be useful. When once found to be navigable, a waterway remains so.[27] This is no more indefinite than a rule of navigability in fact as adopted below based upon "useful interstate commerce" or "general and common usefulness for purposes of trade and commerce" if these are interpreted as barring improvements.[28] Nor is it necessary that the improvements should be actually completed or even authorized. The power of Congress over commerce is not to be hampered because of the necessity for reasonable improvements to make an interstate waterway available for traffic.

Of course there are difficulties in applying these views. Improvements that may be entirely reasonable in a thickly populated, highly developed, industrial region may have been entirely too costly for the same region in the days of the pioneers. The changes in engineering practices or the coming of new industries with varying classes of freight may affect the type of the improvement. Although naviga-

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[25] United States *v.* Oregon, 295 U. S. 1, 15.

[26] Thus in the Rio Grande case, the record contained reports of army engineers that improvements necessary to make the river navigable would be financially, if not physically, impracticable because of the many millions of dollars that would be required. The supreme court of the Territory of New Mexico observed that "the navigability of a river does not depend upon its susceptibility of being so improved by high engineering skill and the expenditure of vast sums of money, but upon its natural present conditions" (9 N. M. 292, 299). This Court agreed that too much improvement was necessary for the New Mexico stretch of the river to be considered navigable. United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 699.

[27] Economy Light Co. *v.* United States, 256 U. S. 113.

[28] See 107 F. (2d) at 780.

bility to fix ownership of the river bed[29] or riparian rights[30] is determined as the cases just cited in the notes show, as of the formation of the Union in the original states or the admission to statehood of those formed later, navigability, for the purpose of the regulation of commerce, may later arise.[31] An analogy is found in admiralty jurisdiction,[32] which may be extended over places formerly non-navigable.[33] There has never been doubt that the navigability referred to in the cases was navigability despite the obstruction of falls, rapids, sand bars, carries or shifting currents.[34] The plenary federal power over commerce must be able to develop with the needs of that commerce which is the reason for its existence. It cannot properly be said that the federal power over navigation is enlarged by the improvements to the waterways. It is merely that improvements make applicable to certain waterways the existing power over commerce.[35] In determining the navigable character of the New River it is proper to consider the feasibility of interstate use after reasonable improvements which might be made.[36]

Nor is it necessary for navigability that the use should be continuous. The character of the region, its products and the difficulties or dangers of the navigation influence the regularity and extent of the use.[37] Small traffic compared to the available commerce of the

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[29] Shively *v.* Bowlby, 152 U. S. 1, 18 and 26; United States *v.* Utah, 283 U. S. 64, 75.

[30] Oklahoma *v.* Texas, 258 U. S. 574, 591, 594; United States *v.* Oregon, 295 U. S. 1, 14.

[31] Cf. United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 699.

[32] Art. III, section 2, cl. 1. Cf. Genessee Chief *v.* Fitzhugh, 12 How. 443.

[33] The Robert W. Parsons, 191 U. S. 17, 28; Ex-parte Boyer, 109 U. S. 629; Marine Transit Co. *v.* Dreyfus, 284 U. S. 263, 271–272.

[34] The Montello, 20 Wall. 430, 442–43; Economy Light Co. *v.* United States, 256 U. S. 113, 122; United States *v.* Utah, 283 U. S. 64, 86. See also Mr. Justice McLean in Spooner *v.* McConnell, 22 Fed. Cas. No. 13,245, at p. 944 (C. C. D. Ohio 1838).

[35] Illustrative of this natural growth is United States *v.* Cress, 243 U. S. 316, involving riparian proprietors' rights where improvements raise the river level so that uplands are newly and permanently subjected to the servitude of public use for navigation. Compensation was decreed for the taking with a declaration that the waterways in question, as artificially improved, remained navigable waters of the United States (pp. 325 and 326). Cf. Arizona *v.* California, 283 U. S. 423, 454.

[36] Cf. Barnes *v.* United States, 46 Ct. Cl. 7, 28.

[37] United States *v.* Utah, 283 U. S. 64; Arizona *v.* California, 283 U. S. 423, 452–54.

region is sufficient.[38] Even absence of use over long periods of years, because of changed conditions, the coming of the railroad or improved highways does not affect the navigability of rivers in the constitutional sense.[39] It is well recognized too that the navigability may be of a substantial part only of the waterway in question.[40] Of course, these evidences of non-navigability in whole or in part are to be appraised in totality to determine the effect of all. With these legal tests in mind we proceed to examine the facts to see whether the 111-mile reach of this river from Allisonia to Hinton, across the Virginia-West Virginia state line, has "capability of use by the public for the purposes of transportation and commerce."[41]

Physical Characteristics. New River may be said to assume its character as such at the mouth of Wilson Creek near the North Carolina-Virginia line. From that point it flows first in a northeast and then in a northwest direction something over 250 miles to Kanawha Falls, West Virginia. It passes through Allisonia and Radford, Virginia, and then Hinton, West Virginia. It is joined by many tributaries, the largest of which is the Gauley. At Kanawha Falls it changes its name to the Kanawha, a navigable river of commercial importance which joins the Ohio, 97 miles below. The whole territory traversed by the New is broken and mountainous. Between Hinton and Kanawha Falls, the river is swift and the gorge precipitous. Above Hinton the river flows more slowly, through a broader valley and between less rugged mountains. The same may be said of the area above Radford. Throughout the river there is an abundance of water, and the respondent hardly denies that the flowage suffices if other conditions make the New available for navigation.[42]

It will conserve discussion to appraise the navigability of the 111-mile stretch between Allisonia and Hinton in three sections which together form the whole reach between these points: the 28 miles from Allisonia to Radford, which the United States improved between 1876 and 1883; the 59-mile stretch from Radford to Wiley's Falls, Virginia, never improved except at Wiley's Falls itself; and the 24 miles from Wiley's Falls across the state line to Hinton, West

[38] United States *v.* Utah, 283 U. S. 64, 82.

[39] Ashwander *v.* Tennessee Valley Authority, 297 U. S. 288, 329.

[40] Economy Light Co. *v.* United States, 256 U. S. 113, 124; Arizona *v.* California, 283 U. S. 423, 453.

[41] Cf. The Montello, 20 Wall. 430, 441.

[42] See 23 F. Supp. at 91.

Virginia, which, like the upper section, the Government improved during 1876–1883. We shall examine chiefly the disputed middle section, for as to the others the evidence of navigability is much stronger and that of obstructions much weaker. For instance, the report of the Chief of Engineers for 1873 refers to certain keelboats operating on the river, and his report for 1883 shows that 17 keelboats operated above Hinton. Keelboats were flat-bottomed bateaux, 50 to 70 feet long, with a draft of two feet and a carrying capacity varying up to 10 or 12 tons. They were used commercially to transport lumber, tobacco and other products of the region. The evidence is clear that these bateaux plied from Hinton up to near Glen Lyn with fair regularity through the first decade of this century and well into the second; timber and lumber in large quantities apparently were boated and rafted down to Hinton from various up-river points below Glen Lyn until about the beginning of the World War.[43] Around and above Radford the Chief of Engineers reported two keelboats operating in 1881, eight in 1882, and eight together with a small steamboat in 1883. The corroborating testimony of many witnesses shows that in the 80's these boats carried iron ore and pig iron, as well as produce and merchandise, between Allisonia and New River Bridge, which is a little above Radford.[44] At the Hinton and New River Bridge railroad stations, freight brought in by the keelboats or other river craft was trans-shipped, and freight arriving by rail was forwarded by river.

We come then to a consideration of the crucial stretch from Radford to below Wiley's Falls where junction is made with the interstate reach from Wiley's Falls to Hinton. In the report of the Secretary of War for 1872 appears Hutton's useful mile-by-mile survey of the river from above Allisonia to the mouth of the Greenbrier, which is nearly down to Hinton. It was made as a basis for plans to im-

[43] This is shown by the testimony of Weiss, Peters, Starbuck, Lane, E. M. Smith, Farley, Kenley, Lucas, E. W. Lilly, W. L. Burks, Z. V. Burks, Johnson, Wauhop, Stover, R. Calloway, J. C. Martin, Tomkies, and B. C. Lilly.

[44] E. g., the testimony of R. L. Howard, Graham, J. Breeding, Owen, Z. Farmer, H. B. Allison, J. H. Howard, Peterson, Moore, Likens, Roop, and Ingles.

In 1885 the assistant engineer reported that "from inquiries it is thought that the channel-way made in former years [on the improved sections] still keeps open, and bateaux are in constant use on them, iron having been shipped to New River bridge up to the time of the suspension of the furnaces by the prevailing hard times" (Report of the Chief of Engineers for 1886).

prove the New by federal appropriation.[45] This survey designates the Radford-Wiley's Falls stretch as "mile 46" to "mile 104" inclusive. Eighteen of these miles have grades falling, gradually or abruptly, more than four feet in the mile. Several of these where there are rapids or falls show drops of eight, nine and in one instance 11½ feet. The higher footage represents, of course, miles in which small falls are found. Between these more precipitous sections are many miles of what is called "good water," with a gradual fall of 4 feet or less. Even in miles where the declivity is rapid, the fall is apparently largely in sections containing obstructions. For instance, the 51st mile reads "Rapid, over bowlders and gravel, 1,500 feet long; fall, 8½ feet," and the 100th mile "Neilley's Falls and rapids; whole fall; 11 feet, 6 of it nearly vertical. A sluice 500 feet long, along left bank, will pass them, with 50 feet of rock excavation and 450 feet of bowlders and gravel." Quite frequently where the fall is moderate, other obstructions appear, as the 78th mile "Rapids, 500 feet long, over bowlders and gravel; fall, 2 feet." Large isolated rocks are scattered abundantly throughout the stretch. A geologist testifying for the respondent tells strikingly how the faulting and folding of the surface at this stretch has resulted in the tilting of the rock strata to a steep degree. "In its flow, the water of New River moves along and up the slopes of successive rock strata or ledges . . . this results in a river with numerous ledges of rock strata, some partly submerged, some exposed, which are substantially vertical or standing on end, and which extend across the stream at right angles to the line of flow. . . . The slope of the strata is downward in an upstream direction rather than in a downstream direction," contrary to the usual condition. No other data point to material variations from these descriptions.

Use of the River From Radford to Wiley's Falls. Navigation on the Radford-Wiley's Falls stretch was not large. Undoubtedly the difficulties restricted it and with the coming of the Norfolk & Western and the Chesapeake & Ohio railroads in the 80s, such use as there had been practically ceased, except for small public ferries going from one bank to the other.[46] Well authenticated instances of boating along this stretch, however, exist. In 1819 a survey was made by Moore and Briggs, whom the General Assembly of Virginia had sent to

[45] 17 Stat. 376.

[46] At different times before 1935 ferries crossed the river at no less than ten points along the Radford-Wiley's Falls stretch. In 1935 there were five such public ferries.

report on the availability of the New for improvement. Beginning at the mouth of the Greenbrier they boated up to the mouth of Sinking Creek, some 55 miles, noting the characteristics of the river as they went. They reported that they ascended all falls with their boat, "though, in two or three instances, with considerable difficulty, after taking out our baggage, stores, &c."[47] Sinking Creek is about half way up this stretch of river we are considering.

In 1861 the Virginia General Assembly appropriated $30,000 to improve the New River to accommodate transportation of military stores by bateaux from Central depot [Radford] to the mouth of the Greenbrier.[48] While there is no direct proof that this particular appropriation was spent, reports of the War Department engineers make it clear that the Confederate government effected some improvements on the river.[49] These facts buttress the testimony of several witnesses, one a Confederate veteran, that during the Civil War keelbottom boats brought supplies from Radford to a commissary at the Narrows (about 7 miles above Glen Lyn), and then continued further downstream.[50] This testimony the circuit court of appeals accepted as true.[51]

From the end of the Civil War to the coming of the railroads, the evidence of elderly residents familiar with events along the banks of the river between Radford and Wiley's Falls leaves no doubt that at least sporadic transportation took place in and throughout this stretch. By this it is not meant that the keelboats above Radford and above Hinton, which operated frequently in the improved sections, made regular through trips from Allisonia past Radford

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[47] Report of Moore and Briggs. Fourth and Fifth Annual Reports of the Board of Public Works to the General Assembly of Virginia (1819). Report of the Principal Engineer of the Board of Public Works.

While Marshall was Chief Justice he was head of a Virginia commission which had surveyed part of the New River by boat in 1812, but only going downstream from the mouth of the Greenbrier. Report of the Commissioners, printed 1816.

[48] Virginia Acts of 1861–62, c. 50.

[49] "But little has been done in the way of improving the river since the time of Moore and Briggs, though an effort is said to have been made in that direction by the confederate government in the late war" (Report of Chief of Engineers for 1873). "Experience as developed by the universal fate of the work of the late Confederate States on this river (though this seems to have been injudiciously located and poorly built), is adverse to anything like rigid structures. . . ." (Report of Chief of Engineers for 1879).

[50] Testimony of Snyder, Snidow, Skeen.

[51] 107 F. (2d) at 783.

to Hinton. Through navigation, however, did occur, as is shown by the testimony of a number of witnesses and recognized by the lower courts.[52] There are also numerous references to isolated bits of boating along parts of the Radford-Wiley's Falls reach.[53] And when the Government stopped improvement in 1883, it ordered the boats it was using in the lead mines' division above Allisonia, and at various places downstream, to be brought down the full stretch of the river to Hinton for sale. Under the supervision of the assistant engineer, a derrick boat, four bateaux, and numerous flat boats, skiffs and canoes—more than twenty vessels in all—were taken down to Hinton, a number of them from points above Radford. This was accomplished, as the Chief of Engineers' report shows, despite difficulties occasioned by "weather, low water, and scarcity of labor."[54]

In addition to the testimony of use in the days before railways and good roads, there was a demonstration of the possibility of navigation by a government survey boat with an outboard motor, 16 feet long, five feet wide, drawing $2\frac{1}{2}$ to 3 feet, loaded with a crew of five and its survey equipment. This boat made a round trip from the Narrows, just above Wiley's Falls, to Allisonia, a distance of 72 miles one way, in July, 1936, when the river stage was normal summer low water. While the crew was out of the boat and used poles a number of times, there were no carries or portages. Going upstream it was not necessary to pull or push the boat more than a mile and a quarter and not more than few hundred feet on the return trip.

Use of a stream long abandoned by water commerce is difficult to prove by abundant evidence. Fourteen authenticated instances of use in a century and a half by explorers and trappers, coupled with general historical references to the river as a water route for the early fur traders and their supplies in pirogues and Durham or flat-bottomed craft similar to the keelboats of the New, sufficed upon that phase in the case of the DesPlaines.[55] Nor is lack of commercial

[52] See 23 F. Supp. at 93; 107 F. (2d) at 786.

Testimony of bateaux going from Radford, or above, to Hinton, is given by Flannagan, Linkous, Collins, Webb, Snyder.

A boat, 50 feet by 8, with a gasoline motor, went from Radford to Hinton in 1901, though after the river had been materially raised by a rain.

[53] E.g., testimony of Coleman, Howard, Webb, Snyder, Price, Martin, Anderson.

[54] Report of the Chief of Engineers for 1883. See also testimony of Owen, Crowell, Dickinson.

[55] Economy Light Co. *v.* United States, 256 Fed. 792, 797–98; affirmed 256 U. S. 113.

traffic a bar to a conclusion of navigability where personal or private use by boats demonstrates the availability of the stream for the simpler types of commercial navigation.[56]

The evidence of actual use of the Radford-Wiley's Falls section for commerce and for private convenience, when taken in connection with its physical condition make it quite plain that by reasonable improvement the reach would be navigable for the type of boats employed on the less obstructed sections. Indeed the evidence detailed above is strikingly similar to that relied upon by this Court in *United States* v. *Utah*[57] to establish the navigability of the Colorado from Cataract Canyon to the Utah-Arizona boundary line. There had been seventeen through trips over a period of sixty years from the original exploration; and these together with sporadic trips on parts of the stretch, and considerable use—in connection with gold placer mining—of other parts from 1888 to 1915, sufficed to sustain navigability.[58]

Effect of Improvability. Respondent denied the practicability of artificial means to bring about the navigability of the New River and the effectiveness of any improvement to make the river a navigable water of the United States. The Government supported its allegation of improvability by pointing out that the use of the section for through navigation and local boating on favorable stretches of the Radford-Wiley's Falls reach showed the feasibility of such use and that little was needed in the way of improvements to make the section a thoroughfare for the typical, light commercial traffic of the area. Keelboats, eight feet wide, drawing two feet, were the usual equipment. In the 1872 report of the Chief of Engineers, Major Craighill in charge of New River reports that to get "good sluice navigation of 2 feet at all times" for 54 miles up from the mouth of the Greenbrier River, near Hinton, would cost $30,000 and for 128 miles, Greenbrier to the lead mines (above Allisonia), would cost $100,000. The depth over the shoals could be increased to 2 feet without "too much increase of velocity of the current." This recommendation was based on Hutton's mile-by-mile survey and includes all of the Radford-Wiley's Falls section.

The improvements were undertaken beginning in 1877. As the region was becoming better developed, a higher type of improvement became desirable, wider sluice ways and a deeper channel, usable

[56] United States *v.* Utah, 283 U. S. 64, 82.

[57] 283 U. S. 64, 81.

[58] See the Report of the Master, p. 127 *et seq.*

by small steamboats. Work went forward above Hinton and above Radford to meet the pressing demands of the communities. Annual reports of the Chief of Engineers assumed or reaffirmed the navigability of the entire river above Hinton and the practicality of the improvements.[59] By 1891, $109,733.21 had been spent. It was in that year estimated $159,000 more would be required to complete the project the full length from Wilson Creek to Hinton.[60] Useful navigation moved regularly between Hinton and near Glen Lyn and between Radford and Allisonia. About half the reach between Hinton and Allisonia was improved. The Radford-Wiley's Falls section was never improved. It was reported that conditions had changed and the project should not be completed.[61] The provisions for improvements were repealed in 1902.[62] By 1912 the region's need for use of the river had so diminished that the army engineers advised against undertaking improvements again, and even referred to the cost as "prohibitive."[63] From the use of the Radford-Wiley's Falls stretch and the evidence as to its ready improvability at a low cost for easier keelboat use, we conclude that this section of the New River is navigable. It follows from this, together with the undisputed commercial use of the two stretches above Radford and Hinton, that the New River from Allisonia, Virginia, to Hinton, West Virginia, is a navigable water of the United States.

License Provisions. The determination that the New River is navigable eliminates from this case issues which may arise only where the river involved is non-navigable.[64] But even accepting the navigability of the New River, the respondent urges that certain provisions of the license, which seek to control affairs of the licensee, are unconnected with navigation and are beyond the power of the Commission, indeed beyond the constitutional power of Congress to authorize.

The issue arises because of the prayer of the bill that the respondent be compelled to accept the license as required by law or remove

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[59] Reports for 1878, pp. 69, 495–99; 1879, pp. 79, 530–45; 1880, pp. 107–08, 676–81; 1881, pp. 144–45, 904–11; 1882, pp. 140–42, 913–19; 1883, pp. 144–45, 699–705; 1886, pp. 281–82, 1599–1602.

[60] Report of the Chief of Engineers for 1891, p. 303.

[61] *Id.*, at 302–303.

[62] 32 Stat. 374.

[63] House Doc. No. 1410, 62nd Cong., 3d Sess., p. 3.

[64] Cf. United States *v.* Appalachian Electric Power Co., 107 F. (2d) 769, 793 *et seq.*

the dam as an obstruction and the answer of the respondent that the license required by law and tendered to it by the Commission contains provisions, unrelated to navigation or the protection of navigable capacity, which are beyond the constitutional authority of Congress to require on account of the Fifth and Tenth Amendments. There is no contention that the provisions of the license are not authorized by the statute. In the note below[65] the chief statutory conditions for a license are epitomized. The license offered the respondent on May 5, 1931, embodied these statutory requirements and we assume it to be in conformity with the existing administration of the Power Act. We shall pass upon the validity of only those provisions of the license called to our attention by the respondent as being unrelated to the purposes of navigation. These are the conditions derived from sections 10a, 10c, 10d, 10e and 14.

[65] §4(a) of the Act allows the Commission to regulate the licensee's accounts.

§6 limits licenses to 50 years.

§8 requires Commission approval for voluntary transfers of licenses or rights granted thereunder.

§10(a) as amended in 1935, requires that the project be best adapted to a comprehensive plan for improving or developing the waterway for the use or benefit of interstate or foreign commerce, for the improvement and utilization of water-power development, and for other beneficial public uses, including recreational purposes. Under §10(c) the licensee must maintain the project adequately for navigation and for efficient power operation, must maintain depreciation reserves adequate for renewals and replacements, and must conform to the Commission's regulations for the protection of life, health and property; (d) out of surplus earned after the first 20 years above a specified reasonable rate of return, the licensee must maintain amortization reserves to be applied in reduction of net investment; (e) the licensee must pay the United States reasonable annual charges for administering the Act, and during the first 20 years the United States is to expropriate excessive profits until the state prevents such profits; (f) the licensee may be ordered to reimburse those by whose construction work it is benefited.

By §11, for projects in navigable waters of the United States the Commission may require the licensee to construct locks, etc., and to furnish the United States free of cost (a) lands and rights-of-way to improve navigation facilities, and (b) power for operating such facilities.

§14 gives the United States the right, upon expiration of a license, to take over and operate the project by paying the licensee's "net investment" as defined, not to exceed fair value of the property taken. However, the right of the United States or any state or municipality to condemn the project at any time is expressly reserved.

§19 allows state regulation of service and rates; if none exists, the Commission may exercise such jurisdiction.

We do not consider that the validity of other clauses has been raised by the respondent's general challenge to the constitutionality of any provision "other than those relating solely to the protection" of navigable waters.[66] It should also be noted that no complaint is made of any conditions of the license dependent upon the authorization of §10g, the omnibus clause requiring compliance with such other conditions as the Commission may require.

The petitioner suggests that consideration of the validity of section 14, the acquisition clause, and the license conditions based upon its language are properly to be deferred until the United States undertakes to claim the right to purchase the project on the license terms fifty years after its issuance.[67] Assuming that the mere acceptance of a license would not later bar the objection of unconstitutional conditions, even when accompanied by a specific agreement to abide by the statute and license,[68] we conclude that here the requirements of section 14 so vitally affect the establishment and financing of respondent's project as to require a determination of their validity before finally adjudging the issue of injunction.

The respondent's objections to the statutory and license provisions, as applied to navigable streams, are based on the contentions (1) that the United States' control of the waters is limited to control for purposes of navigation, (2) that certain license provisions take its property without due process, and (3) that the claimed right to acquire this project and to regulate its financing, records and affairs, is an invasion of the rights of the states, contrary to the Tenth Amendment.

Forty-one states join as amici in support of the respondent's arguments. While conceding, as of course, that Congress may prohibit the erection in navigable waters of the United States of any structure deemed to impair navigation, the Attorneys General speaking for the states insist that this power of prohibition does not comprehend a power to exact conditions, which are unrelated to navigation, for the permission to erect such structures. To permit, the argument continues, the imposition of licenses involving conditions such as this acquisition clause, enabling the Federal Government to

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[66] Denver Stock Yard Co. *v.* United States, 304 U. S. 470, 484; Pacific States Co. *v.* White, 296 U. S. 176, 184.

[67] Cf. Electric Bond & Share Co. *v.* Securities and Exchange Comm., 303 U. S. 419, 435; W. W. Cargill Co. *v.* Minnesota, 180 U. S. 452, 468; New Jersey *v.* Sargent, 269 U. S. 328, 339.

[68] Section 6.

take over a natural resource such as water-power, allows logically similar acquisition of mines, oil or farmlands as consideration for the privilege of doing an interstate business. The states thus lose control of their resources and property is withdrawn from taxation in violation of the Tenth Amendment.

Further, the point is made that a clash of sovereignty arises between the license provisions of the Power Act and state licensing provisions. The Commonwealth of Virginia advances forcibly its contention that the affirmative regulation of water-power projects on its navigable streams within its boundaries rests with the state, beyond that needed for navigation. "While the supremacy of the Federal Government in its own proper sphere, as delineated in the Constitution, is cheerfully conceded, yet just as earnestly does Virginia insist upon the supremacy of her own government in its proper field as established by that instrument." Virginia has a Water Power Act.[69] It, too, offers a fifty-year license, with the right to use the natural resources of the state, the stream flow and the beds of the water courses for the period of the license or its extensions subject to state condemnation at any time on Virginia's terms for ascertainment of value. Operation is likewise regulated by state law.[70] The Commonwealth objects that the development of its water power resources is subjected to Federal Power Act requirements such as are detailed above in stating the respondent's objection, even to the point that Virginia itself may not build and operate a dam in navigable water without authorization and regulation by the Federal Government.

The briefs and arguments at the bar have marshaled reasons and precedents to cover the wide range of possible disagreement between Nation and state in the functioning of the Federal Power Act. To predetermine, even in the limited field of water power, the rights of different sovereignties, pregnant with future controversies, is beyond the judicial function. The courts deal with concrete legal issues, presented in actual cases, not abstractions.[71] The possibility of other uses of the coercive power of license, if it is here upheld, is not before us. We deem the pictured extremes irrelevant save as possibilities for consideration in determining the present question

[69] Michie's 1936 Code, §§3581 (1)-(16).

[70] Michie's 1936 Code, §§4065a, 4066.

[71] Cherokee Nation *v.* Georgia, 5 Pet. 1, 75; United States *v.* West Virginia, 295 U. S. 463, 474; New Jersey *v.* Sargent, 269 U. S. 328; cf. McGuinn *v.* High Point, 217 N. C. 449, 458.

of the validity of the challenged license provisions. To this we limit this portion of our decision.[72]

The respondent is a riparian owner with a valid state license to use the natural resources of the state for its enterprise. Consequently it has as complete a right to the use of the riparian lands, the water, and the river bed as can be obtained under state law. The state and respondent, alike, however, hold the waters and the lands under them subject to the power of Congress to control the waters for the purpose of commerce.[73] The power flows from the grant to regulate, i.e., to "prescribe the rule by which commerce is to be governed."[74] This includes the protection of navigable waters in capacity as well as use.[75] This power of Congress to regulate commerce is so unfettered that its judgment as to whether a structure is or is not a hindrance is conclusive. Its determination is legislative in character.[76] The Federal Government has domination over the water power inherent in the flowing stream. It is liable to no one for its use or non-use. The flow of a navigable stream is in no sense private property; "that the running water in a great navigable stream is capable of private ownership is inconceivable." Exclusion of riparian owners from its benefits without compensation is entirely within the Government's discretion.[77]

Possessing this plenary power to exclude structures from navigable waters and dominion over flowage and its product, energy, the United States may make the erection or maintenance of a structure in a navigable water dependent upon a license.[78] This power is exercised through section 9 of the Rivers and Harbors Act of 1899 prohibiting construction without Congressional consent and through section 4 (e) of the present Power Act.

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[72] Ashwander *v.* Tennessee Valley Authority, 297 U. S. 288, 339.

[73] New Jersey *v.* Sargent, 269 U. S. 328, 337; United States *v.* River Rouge Co., 269 U. S. 411, 419; United States *v.* Cress, 243 U. S. 316, 320; Willink *v.* United States, 240 U. S. 572, 580; United States *v.* Chandler-Dunbar Co., 229 U. S. 53, 62; Gibson *v.* United States, 166 U. S. 269, 271.

[74] Gibbons *v.* Ogden, 9 Wheat. 1, 196.

[75] Gilman *v.* Philadelphia, 3 Wall. 713, 725.

[76] United States *v.* Chandler-Dunbar Co., 229 U. S. 53, 64, 65; Union Bridge Co. *v.* United States, 204 U. S. 364, 400; cf. Pennsylvania *v.* Wheeling Bridge Co., 13 How. 518, 18 How. 421.

[77] United States *v.* Chandler-Dunbar Co., 229 U. S. 53, 66, 69, 76; cf. Ashwander *v.* Tennessee Valley Authority, 297 U. S. 288, 330.

[78] Greenleaf Lumber Co. *v.* Garrison, 237 U. S. 251, 268; United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 707.

It is quite true that the criticized provisions summarized above are not essential to or even concerned with navigation as such. Respondent asserts that the rights of the United States to the use of the waters is limited to navigation. It is pointed out that the federal sovereignty over waters was so described in *Port of Seattle* v. *Oregon & Washington Railroad Company*,[79] *United States* v. *Oregon*,[80] *Kansas* v. *Colorado*,[81] *United States* v. *River Rouge Company*,[82] and *Wisconsin* v. *Illinois*.[83] The first two of these cases centered around the issue of title to land under navigable water. Nothing further was involved as to the use of the water than its navigability. In *Kansas* v. *Colorado* the point was the Government's advocacy of the doctrine of sovereign and inherent power to justify the United States taking charge of the waters of the Arkansas to control the reclamation of arid lands (pp. 85–89). There was found no constitutional authority for irrigation in the commerce clause or the clause relating to property of the United States.[84] It cannot be said, however, that the case is authority for limiting federal power over navigable waters to navigation,[85] especially since the stretch of the Arkansas River involved in the dispute was asserted by the Government to be non-navigable (p. 86). In the *River Rouge* controversy, this Court spoke of the limitation "to the control thereof for the purposes of navigation." But there, too, it was a question of the riparian owner's use of his property for access to the channel, a use fixed by state law. The conclusion that the United States could not interfere, except for navigation, with his right of access to navigable water, required no appraisal of other rights. *Wisconsin* v. *Illinois* is a part of the Chicago Drainage Canal litigation. In so far as pertinent here, it merely decided that under a certain federal statute[86] there was no authority for diversion of the waters of Lake Michigan for sanitary purposes (p. 418). There is no consideration of the constitutional power to use water for other than navigable purposes, though it is plain that other advantages occur (pp. 415, 419).

[79] 255 U. S. 56, 63.
[80] 295 U. S. 1, 14.
[81] 206 U. S. 46, 85–86.
[82] 269 U. S. 411, 419.
[83] 278 U. S. 367, 415.
[84] Art. IV, §3, cl. 2.
[85] Cf. United States *v.* Hanson, 167 Fed. 881, 884; Cincinnati Soap Co. *v.* United States, 301 U. S. 308, 322.
[86] Cf. Sanitary District *v.* United States, 266 U. S. 405, 428.

In our view, it cannot properly be said that the constitutional power of the United States over its waters is limited to control for navigation. By navigation respondent means no more than operation of boats and improvement of the waterway itself. In truth the authority of the United States is the regulation of commerce on its waters. Navigability, in the sense just stated, is but a part of this whole. Flood protection, watershed development, recovery of the cost of improvements through utilization of power are likewise parts of commerce control.[87] As respondent soundly argues, the United States cannot by calling a project of its own "a multiple purpose dam" give to itself additional powers, but equally truly the respondent cannot, by seeking to use a navigable waterway for power generation alone, avoid the authority of the Government over the stream. That authority is as broad as the needs of commerce. Water power development from dams in navigable streams is from the public's standpoint a by-product of the general use of the rivers for commerce. To this general power, the respondent must submit its single purpose of electrical production. The fact that the Commission is willing to give a license for a power dam only is of no significance in appraising the type of conditions allowable. It may well be that this portion of the river is not needed for navigation at this time. Or that the dam proposed may function satisfactorily with others, contemplated or intended. It may fit in as a part of the river development. The point is that navigable waters are subject to national planning and control in the broad regulation of commerce granted the Federal Government. The license conditions to which objection is made have an obvious relationship to the exercise of the commerce power. Even if there were no such relationship the plenary power of Congress over navigable waters would empower it to deny the privilege of constructing an obstruction in those waters. It may likewise grant the privilege on terms. It is no objection to the terms and to the exertion of the power that "its exercise is attended by the same incidents which attend the exercise of the police power of the states."[88] The Congressional authority under the commerce clause is complete unless limited by the Fifth Amendment.

The respondent urges that as riparian owner with state approval of its plans, it is entitled to freedom in the development of its

[87] Cf. Ashwander *v.* Tennessee Valley Authority, 297 U. S. 288.

[88] United States *v.* Carolene Products Co., 304 U. S. 144, 147. Cf. Mulford *v.* Smith, 307 U. S. 38, 48.

property and particularly cannot be compelled to submit to the acquisition clause with a price fixed at less than a fair value, in the eminent domain sense, at the time of taking. Such a taking, it is contended, would violate the Fifth Amendment. It is now a question whether the Government in taking over the property may do so at less than a fair value. It has been shown, note 77, *supra*, that there is no private property in the flow of the stream. This has no assessable value to the riparian owner. If the Government were now to build the dam, it would have to pay the fair value, judicially determined,[89] for the fast land; nothing for the water power.[90] We assume without deciding that by compulsion of the method of acquisition provided in section 14 of the Power Act and the tendered license, these riparian rights may pass to the United States for less than their value. In our view this "is the price which [respondents] must pay to secure the right to maintain their dam." The quoted words are the conclusion of the opinion in *Fox River Company* v. *Railroad Commission*.[91] The case is decisive on the issue of confiscation. It relates to an acquisition clause in a Wisconsin license by which a dam in navigable water of the state might be taken over at such a price as would, this Court assumed, amount to violation of the due process clause of the Fourteenth Amendment if it were not for the license provision. Title to the bank and bed were in the objector, just as, by virtue of the state's license and the riparian ownership, all rights here belong to respondent. There, as here, the rights were subject to governmental "control of navigable waters."[92] The fact that the *Fox River* case involved a state and that this case involves the United States is immaterial from the due process standpoint. Since the United States might erect a structure in these waters itself, even one equipped for electrical generation,[93] it may constitutionally acquire one already built.

Such an acquisition or such an option to acquire is not an invasion of the sovereignty of a state. At the formation of the Union, the states delegated to the Federal Government authority to regulate commerce among the States. So long as the things done within the states by the United States are valid under that power, there can

[89] Monongahela Navigation Co. *v.* United States, 148 U. S. 312, 327.

[90] United States *v.* Chandler-Dunbar Co., 229 U. S. 53, 66, 76.

[91] 274 U. S. 651.

[92] *Id.*, 656.

[93] Ashwander *v.* Tennessee Valley Authority, 297 U. S. 288; Arizona *v.* California, 283 U. S. 423.

be no interference with the sovereignty of the state. It is the non-delegated power which under the Tenth Amendment remains in the state or the people. The water power statutes of the United States and of Virginia recognize the difficulties of our dual system of government by providing, each in its own enactments, for the exercise of rights of the other.[94]

Reversed and remanded to the District Court with instructions to enter an order enjoining the construction, maintenance or operation of the Radford project otherwise than under a license, accepted by the respondent within a reasonable time, substantially in the form tendered respondent by the Federal Power Commission on or about May 5, 1931, or in the alternative, as prayed in the bill.

The CHIEF JUSTICE took no part in the consideration or decision of this case.

Dissenting Opinion

Mr. Justice ROBERTS.

The judgment of reversal rests on the conclusion that New River is navigable,—a conclusion resting on findings of fact, made here *de novo*, and in contradiction of the concurrent findings of the two courts below. I am of opinion that the judgment of the Circuit Court of Appeals should be affirmed, first, because this court ought to respect and give effect to such concurrent findings which have substantial support in the evidence; secondly, because the evidence will not support contrary findings if the navigability of New River be tested by criteria long established.

1. A river is navigable in law if it is navigable in fact.[1] Indeed the issue of navigability *vel non* is so peculiarly one of fact that a determination as to one stream can have little relevancy in determining the status of another. As this court has said, "each determination as to navigability must stand on its own facts."[2]

The evidence supports,—indeed I think it requires,—a finding that, applying accepted criteria, New River is not, and never has been, in fact navigable. On this record the rule of decision, many

[94] §§10e, 14 and 19 of the Federal Power Act; Michie's 1936 Virginia Code, §3581 (10).

[1] Oklahoma *v.* Texas, 258 U. S. 574, 585, 590–1; Arizona *v.* California, 283 U. S. 423, 452; Crowell *v.* Benson, 285 U. S. 22, 55.

[2] United States *v.* Utah, 283 U. S. 64, 87.

times announced by this court, that the concurrent findings of fact of two lower courts, if supported by substantial evidence, will be accepted here, requires affirmance of the judgment. The rule applies not only to evidentiary facts but to conclusions of fact based thereon. Moreover, it has been the basis of this court's decision in a suit involving the question of navigability. Invoking the rule, this court, in *Brewer-Elliott Oil & Gas Co.* v. *United States*, 260 U. S. 77, 86, declined to review a judgment based on a concurrent finding of two lower courts that a stream "was not, and had never been, navigable within the adjudged meaning of that term."

The cases cited for the proposition that where navigability was an issue this court has reconsidered the facts found by the courts below to determine whether they have correctly applied the proper legal tests do not, when the questions involved are understood, lend support to the action of the court in this case.[3]

The petitioner, in effect, asks this court to convict the courts below of error in determining the credibility, weight and relevance of the evidence. But that determination is peculiarly within their province, as this court has often said. The doctrine applies in this case with especial force. The respondent says, without contradiction, that the Government in its brief in the Circuit Court stated: "It cannot be said that the New River presents a 'clear case' of navigability or non-navigability . . .". Yet this court is asked to ignore concurrent findings on the subject.

If the evidence may fairly support these findings, the courts below can be convicted of error only in applying an erroneous rule of law to the facts found.

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[3] The cases cited are United States *v.* Rio Grande Irrigation Co., 174 U. S. 690, 699, where this court said with respect to the findings: "We are not, therefore, disposed to question the conclusion reached," by the courts below; Leovy *v.* United States, 177 U. S. 621, where a judgment on a jury's verdict was reversed for error in the judge's instructions as to the criteria of navigability; Economy Light Co. *v.* United States, 256 U. S. 113, 117, where the court did not re-examine the facts but affirmed the judgment of the Circuit Court of Appeals, as that court had correctly applied the test laid down in The Daniel Ball; and United States *v.* Holt Bank, 270 U. S. 49, 55, where the courts below treated the question of navigability as one of local law to be determined by applying the rule adopted in Minnesota, and this court, though holding that they applied the wrong standard, as the question was one of federal law, affirmed the findings, instead of remanding the case, since the record disclosed that according to the right standard the water was navigable.

Examination of the opinions below shows that the courts faithfully followed the decisions of this court in applying the law to the facts. They adopted the definition[4] and applied the criteria this court has announced in appraising the effect of the facts found.

As shown by the cases cited in the margin,[5] a stream to be navigable in fact must have "a capacity for general and common usefulness for purposes of trade and commerce." Exceptional use or capability of use at high water or under other abnormal conditions will not suffice. Moreover, the stream must be used, or available to use, "for commerce of a substantial and permanent character." Where the stream "has never been impressed with the character of navigability by past use in commerce, . . . commerce actually *in esse* or at least *in posse* is essential to navigability" and "a theoretical or potential navigability or one that is temporary, precarious and unprofitable is not sufficient." The most important criterion by which to ascertain the navigability of a stream is that navigability in fact must exist under "natural and ordinary conditions." Application of these tests by the court below to the evidence in the case led to but one conclusion—that New River has not been, and is not now, a navigable water of the United States. If the findings below had been the other way, the Government would be here strenuously contending that they could not be set aside, as it successfully did in *Brewer-Elliott Oil & Gas Co.* v. *United States, supra.*

2. The petitioner contends that the application of the accepted tests to the facts disclosed amounts to a ruling of law, and asserts that error in their application is reviewable. As I read the court's opinion, the argument is not found persuasive. While apparently endorsing it in the abstract the court, instead of relying on it, adopts two additional tests in the teeth of the uniform current of authority. If anything has been settled by our decisions it is that, in order for a water to be found navigable, navigability in fact must exist under "natural and ordinary conditions." This means all conditions, including a multiplicity of obstacles, falls and rapids which make

[4] Cf. The Daniel Ball, 10 Wall. 557; The Montello, 11 Wall. 411, 415; United States *v.* Oregon, 295 U. S. 1, 23.

[5] The Montello, 20 Wall. 430; United States *v.* Rio Grande Co., 174 U. S. 690; Leovy, *v.* United States, 177 U. S. 621; Donnelly *v.* United States, 228 U. S. 243; United States *v.* Cress, 243 U. S. 316; Oklahoma *v.* Texas, 258 U. S. 574; United States *v.* Holt State Bank, 270 U. S. 49; United States *v.* Oregon, 295 U. S. 1; Harrison *v.* Fite, 148 Fed. 781; Gulf & I. Ry. Co. *v.* Davis, 26 F. (2d) 930, 31 F. (2d) 109; United States *v.* Doughton, 62 F. (2d) 936.

navigation a practical impossibility. The court now, however, announces that "natural and ordinary conditions" refers only to volume of water, gradients, and regularity of flow. No authority is cited and I believe none can be found for thus limiting the connotation of the phrase. But further the court holds, contrary to all that has heretofore been said on the subject, that the natural and ordinary condition of the stream, however impassable it may be without improvement, means that if, by "reasonable" improvement, the stream may be rendered navigable then it is navigable without such improvement; that "there must be a balance between cost and need at a time when the improvement would be useful." No authority is cited and I think none can be cited which countenances any such test. It is of course true that if a stream in its natural and ordinary condition is navigable it does not cease to be so because improvements have bettered the conditions of navigation.[6] But the converse is not true,—that where a stream in its natural and ordinary condition is non-navigable, a project to build a canal along its entire course, or dams and locks every few miles, at enormous expense, would render it a navigable water of the United States. Who is to determine what is a reasonable or an unreasonable improvement in the circumstances; or what is a proper balance between cost and need? If these questions must be answered it is for Congress, certainly not for this court to answer them. If this test be adopted, then every creek in every state of the Union which has enough water, when conserved by dams and locks or channelled by wing dams and sluices, to float a boat drawing two feet of water, may be pronounced navigable because, by the expenditure of some enormous sum, such a project would be possible of execution. In other words, Congress can create navigability by determining to improve a non-navigable stream.

If this criterion be the correct one, it is not seen how any stream can be found not to be navigable nor is it seen why this court and other federal courts have been at pains for many years to apply the other tests mentioned when the simple solution of the problem in each case would have been to speculate as to whether, at "reasonable" cost, the United States could render a most difficult and forbidding mountain torrent suitable for the least pretentious form of water traffic. In the light of the court's opinion, if this test be applied to the New River it must, of course, be admitted that by blasting out

[6] Economy Light Co. *v.* United States, 256 U. S. 113.

channels through reefs and shoals, by digging canals around falls and rapids, and possibly by dams and locks, the New River could be rendered fit for some sort of commercial use. What the expense would be no one knows. Obviously it would be enormous. Congress in the past has undertaken to render the river navigable and decades ago gave up the attempt. Still we are told that, at "reasonable" cost, the thing can be done, and so the stream is navigable.

In the light of the grounds upon which the decision of the court is based it hardly seems necessary to comment on the evidence, for it is in the main addressed to issues no longer in the case. The two courts below have analyzed it and examined it in detail and reference to their carefully considered opinions suffices.[7] I think the conclusion reached by the courts below must stand unless the two novel doctrines now announced be thrown into the scale to overcome it.

Mr. Justice McREYNOLDS concurs in this opinion.

[7] 23 F. Supp. 83; 107 F. (2d) 769.

EDITORIAL NOTE: On December 16, 1940, the Supreme Court of the United States rendered a decision upon what has come to be termed the "New River Case."

This matter became the subject of legal action when the Appalachian Electric Power Company undertook to build a power dam on the New River just above Radford, Virginia, and was refused authority to do so by the Federal Power Commission. Both the District and Appeals Federal Courts found that the New River was not navigable *in fact*.

The Supreme Court decision implies that the New River is *in effect* navigable insofar as the results which may accrue upon the factually navigable portions of the streams to which the New River is tributary.

The decision, in effect, abrogates the practices of the states and all previous rulings of the Court which assumed the complete power of the states to regulate and control non-navigable intrastate waters.

It may be expected that in the future this decision will tend to support the substitution of federal for state control of even the smallest streams for any use to which flowing surface water may be put. Thus the decision becomes a matter of interest to municipal water departments which may find in the future, when they propose to divert or impound intrastate surface waters, that a federal agency is in a position of authority once exercised by state authorities.

Because of the bearing which this decision has upon the entire water works field, it has been advisable to reproduce the decision in full.

Report of the Committee on Water Works Practice

HEREWITH is a report presented to the Board of Directors of the American Water Works Association at its annual meeting on January 13 and 14, 1941. A complete list of all Association Committees will be found beginning on Page 186 of the July, 1940, Membership Supplement. A record of action taken by the Board, along the lines indicated in this report, appears in Appendix B (p. 363).

The report is a summary of the activities of the various sub-committees of the Committee on Water Works Practice. It also includes a report of the progress of various inter-association committees in which work the American Water Works Association participates, as well as a report of activities of committees of other associations to which activities the American Water Works Association has appointed a representative.

Water Works Practice Committees

1. *Deep Wells and Deep Well Pumps.* Messrs. Carr and Harding, co-chairmen of this committee, now have completed the first draft of the proposed specifications for deep wells and for deep well pumps. The material has been reviewed by Reeves Newsom, advisor to the committee, and has been submitted to the members of the committee for their approval. It is expected that these documents will be sufficiently advanced by the time of the 1941 General Convention for some discussion of them at that time.

2. *Manual of Water Quality and Treatment.* The text of this manual was published and made available for sale in April 1940. Only 140 copies of the original printing of 1,000 copies remained at the end of 1940.

3. *History of Water Purification.* M. N. Baker, retired editor of the *Engineering News-Record*, has for more than five years been giving much of his time to research concerning the development of public water supplies on the North American continent and the development of water treatment processes both in Europe and in

North America. While the A.W.W.A. has planned to publish this material whenever the editor indicated that it was ready for publication, a definite record of the intended extent of the text has never been made.

Suggestions have been made that Mr. Baker contemplate the condensation of the material to a scope that would be limited by 400 printed pages and make the material available to the Publication Committee some time during the year 1941. Mr. Baker has also incurred certain expenses in the purchase of original documents from England and the continent for which expense it would appear proper to reimburse him, if the documents thus became the property of the A.W.W.A.

4. *Chemical Hazards in Water Works Plants.* Certain discussions which have been carried on with Mr. Marsden Smith, Chairman of this committee, indicate the advisability of changing the name of the committee to "Safe Handling of Water Works Chemicals." Strictly speaking, the rephrased title of the committee is more in keeping with its actual purpose. The chairman proposes to direct the attention of his committee to a study of activated carbon and the procedures which are essential to safe and satisfactory handling of the material in water treatment processes. This work will be carried on during the present year.

5. *Steel Plate Pipe.* As the result of the activities of this committee, under the leadership of W. W. Hurlbut, seven sets of specification documents have been made available to the water works field during the year 1940. Four of the specifications are standard documents, as follows:

7A.1—1940	A.W.W.A. Standard Specifications for Riveted Steel Pipe
7A.3—1940	A.W.W.A. Standard Specifications for Electric Fusion Welded Steel Water Pipe of Sizes 30 Inches and Over
7A.5—1940	A.W.W.A. Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over
7A.6—1940	A.W.W.A. Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes of $4\frac{1}{2}$ Inches Outside Diameter up to but Not Including 30 Inches

Three of the specifications are tentative standards, as follows:

7A.2 *Tentative* A.W.W.A. Standard Specifications for Lock-Bar Pipe

7A.4 *Tentative* A.W.W.A. Standard Specifications for Steel Water Pipe of Sizes of 4 Inches up to but Not Including 30 Inches

7A.7 *Tentative* A.W.W.A. Standard Specifications for Cement-Mortar Protective Coating for Steel Water Pipe of Sizes 30 Inches and Over.

There are current, at present, certain discussions concerning amendments to document 7A.4.

6. *Laying Cast-Iron Pipe.* The chairman of this committee, Wm. C. Mabee, has addressed a communication to the members of his committee, which calls to their attention certain portions of the material published by the A.W.W.A. in 1938 and which now appear to need revision.

The Bureau of Standards is now circulating as a "Proposed Commercial Standard," specifications for calking lead, which were prepared by the Lead Industries Association. The analytical requirements set forth in the proposed commercial standards are the same as those which were included in the 1938 report of the A.W.W.A.'s Committee on Laying Cast-Iron Pipe. The proposed commercial standard includes a reference to the use of the "Seal of Approval" of the Lead Industries Association. This procedure is fairly common in English commercial practice but is not so widely a part of American practice. It would appear to be a reasonable policy of the A.W.W.A. to make reference in its specifications documents to material marketed under a seal of approval, only when the requirements for obtaining such a seal of approval were definitely recorded by memorandum presented to the Committee on Water Works Practice and to the Board of Directors and found to be acceptable to them.

Limitations upon the reference to a seal of approval need not be understood to limit the Association and its technical committees in their references to analytical and technical details of specifications promulgated by other organizations.

7. *Valves, Fire Hydrants and Sluice Gates.*

7.1. *Valves.* The specifications for gate valves were published in 1939. There is at present no discussion current indicating the

need of revision or modification of any portion of these specifications.

7.2. *Fire Hydrants.* The specifications for fire hydrants were published in the JOURNAL for August, 1940. They were approved by the New England Water Works Association in convention on September 26, 1940. Reprints of these specifications will hereafter be made available under certification of their adoption by the two associations.

7.3. *Sluice Gates.* The chairman of the committee on specifications for sluice gates has submitted a third draft of the specifications to the members of his committee and to the members of the Committee on Water Works Practice. Copies of this document will be made available to the members of the Board prior to the time of the 1941 Convention. The specifications will, prior to, or at, that convention, be given thorough discussion by the Committee on Water Works Practice, and if the Committee approves their transmittal, they will be forwarded to the Board of Directors for acceptance as tentative specifications.

8. *Location Records and Maintenance of Mains and Services.* The report of this committee was published in the JOURNAL for February, 1940. It has been well received by the water works field. Several water departments are revising their methods of handling records so that they may be kept according to the methods recommended in the committee report. The chairman of the committee, W. Victor Weir, has brought to the attention of the committee members certain items for consideration as a supplement to the original report. It is planned to present certain recommendations upon the subject to the Committee on Water Works Practice at the time of the 1941 Convention.

9. *Steel Standpipes and Elevated Tanks.* Louis R. Howson is chairman of both the A.W.W.A.'s and the American Welding Society's committees on this subject. Under the leadership of Mr. Howson, the two committees, acting as a unit, prepared the tentative specifications which were published as a part of the December, 1940, issue of the JOURNAL. Reprints of these specifications are now available. After the proper time interval has elapsed, the specifications will be brought to the attention of the Board for approval as standard. It appears proper to record, at this point, that four other

sets of specifications on steel storage tanks are currently available to buyers of this type of equipment, as follows:

1. American Petroleum Institute Specifications on All-Welded Oil Storage Tanks, No. 12-C, Third Edition, April, 1940. These specifications were approved in 1935 and successively revised in 1937, 1938 and 1939.

2. Specifications for Gravity Water Tanks and Steel Towers (No. 11A—1938), issued by the Associated Factory Mutual Fire Insurance Companies.

3. Regulations of the National Board of Fire Underwriters (1931) for the Construction and Installation of Tanks, Gravity and Pressure, Towers, etc., as recommended by the N.F.P.A.

4. Field Welded Water Storage Tanks for Railway Service—American Railway Engineers Association. Revision of these is in progress and is understood to plan the inclusion of specifications covering welded steel tanks.

The A.W.W.A.-A.W.S. specifications were called to the attention of the Secretary of the New England Water Works Association by letter dated December 30, 1940. It was suggested that the N.E.W.W.A. consider approval of the specifications.

10. *Pipe Line Coefficients.* There has been some correspondence during the year 1940 relating to the activities of this committee, but there is in hand no report from the chairman covering the current activities. The attention of the Board is invited to the paper by C. H. Capen, which appears in the January, 1941 issue of the JOURNAL under the title "Trends in Coefficients of Large Pressure Pipes." This appears to be a valuable contribution to the knowledge concerning flow characteristics of large steel pipe lines.

11. *Distribution System Safety.* This important committee under the leadership of its chairman, Wm. E. Stanley, has subdivided its activities under ten headings which are assigned to various individuals on the committee. Preliminary drafts of some of the statements indicate fully constructive activity. It is evident that the Association can anticipate, within a relatively short period of time, an authoritative code for distribution system safety. Since such a document, when completed, will have material bearing upon construction and management policies of the water works field, it is incumbent upon this Board, whenever such documents are submitted for consideration and approval, to give them most careful

study to the end that the completed material gives full and constructive service to all water supply enterprises.

12. *Cross-Connections.* The Committee on Cross-Connections is preparing a report to be presented at the 1941 Convention of the Association. This report will deal with the following subjects upon which sub-committees are now working:

(a) Status of cross-connection control in the United States, Canada and Mexico.

(b) Problem of dual supplies in industrial plants.

(c) Cross-connections between private potable supplies and public supplies.

This report will include a glossary and a bibliography and will conclude with specific recommendations concerning policies for the Association relating to the subject of the report.

13. *Fire Prevention and Protection.* This committee, under the chairmanship of C. J. Alfke, is preparing a primer relative to private fire protection charges—more particularly to the basis for arriving at the charges and the reasons for making full and complete charge for the service. It is hoped to have this material available at the time of the 1941 Convention.

14. *Meters.* The fourth revision of proposed specifications for displacement meters will be presented to the Committee on Water Works Practice for their consideration in advance of the 1941 Convention. It is anticipated that the specifications will be presented to the Board at that meeting with the recommendation that they be accepted as "tentative" specifications on displacement meters. The chairman of the committee has in hand, at the present time, preliminary drafts of the specifications for compound and current meters.

15. *Service Line Materials.* A final report of the committee was received from the chairman under date of January 11, 1941. This report is to be sent to the Committee on Water Works Practice for approval as a tentative A.W.W.A. standard specification for service line materials.

16. *Valuation and Depreciation.* A great deal of attention has been given to requests originating with the National Association of Railroad and Utilities Commissioners covering the field of *depreciation*, or, conversely, expressible as the *useful life of water works structures.* A complete presentation of this subject appears as Appendix A of this report.

Water Purification Division Committees

17. *Methods of Water Treatment and Laboratory Control.* This committee under the chairmanship of George D. Norcom has made a number of valuable contributions to the field of water treatment. In the interest of clarifying the purposes of the Water Purification Division, it appears advisable to reconstitute this committee under the title of "Committee on Water Purification Practice." Such a committee, set up upon a reasonably permanent basis by the officers of the Water Purification Division, could be assigned the primary duties of investigating requests made for the appointment of special committees in the field of water treatment. It would be logical to have one of the members of this committee made a member of the Committee on Water Works Practice. It would thus be possible to bring into the Committee on Water Works Practice more definite information concerning the decisions of the members of the Water Purification Division and to relate the research activities of the division more definitely to the Water Works Practice Committee.

18. *Specifications and Tests for Water Purification Chemicals.* This project was established in 1932. The chairman of the committee has done much valuable work, but now finds himself burdened with his duties as a university professor. It may be advisable to bring this material into the Association's office where it may be completed and arranged for publication.

19. *Activated Carbon Research.* This committee is active. Certain of its members are currently engaged in research of value to the Water Purification Division. Some rather sharp issues have arisen concerning the validity of the threshold odor determination. These questions require the attention of the Water Purification Division at its next session.

20. *Specifications for and Methods of Testing Zeolites.* D. E. Davis, chairman of the reconstituted committee on this subject, submitted, under date of November 30, 1940, a tentative report for his committee. Copies of the report were sent to about 100 workers in the field and the comments received are now being given consideration by the committee's chairman. A report for the committee may be anticipated at the time of the 1941 Convention.

21. *Methods of Determining Fluorides.* The final report of this committee is in circulation among the members of the committee for approval.

22. *Chloramination.* While the water purification field has developed an extremely active interest in the efficiency of high chlorine dosages, within the past two years, this committee of the Water Purification Division has not brought its original assignment to completion.

23. *Water Conditioning Methods to Inhibit Corrosion.* W. F. Langelier, who has been chairman of this committee, requested that he be relieved of his responsibility. Professor Edward W. Moore of the Harvard Graduate School of Engineering has taken over the leadership of this committee and is at present engaged in an exchange of correspondence with the members of his committee looking toward certain definite statements at the time of the 1941 Convention.

24. *Standards for Purification Plant Operation.* Chairman Hopkins of this committee has prepared and sent to the members of the committee the first draft of a report. The nature of this report was such as to indicate the propriety of a conference including Secretary Cox of the Water Purification Division, Chairman Norcom of the Committee on Methods of Water Treatment and Laboratory Control, Chairman Hopkins and certain other persons associated in the field of water treatment. This conference has been held and a revised report is now being prepared and will be made available for discussion at the time of the 1941 Convention.

25. *Specifications for Filtering Material.* This committee was organized in 1940 under the chairmanship of Paul Hansen. The chairman plans to present a preliminary report at the 1941 Convention.

26. *Permissible Loadings and Capacities of Water Treatment Plants.* This committee was organized in 1940 with A. Clinton Decker as chairman. It is too early to report any definite results of the activities.

Finance and Accounting Division Committees

27. *Joint Administration and Collection of Water and Sewer Accounts.* L. N. Thompson, Superintendent of the St. Paul Water Department has succeeded F. A. Wallene as chairman of this committee. The chairman contemplates a report for his committee as a part of the proceedings of the Finance and Accounting Division during the 1941 Convention.

28. *Lien Laws.* The chairman of this committee has presented preliminary reports upon the subject, the last of which was a part

of the 1940 Convention proceedings. It has not been published. A more complete report which can be published is anticipated during 1941.

Joint Committees With Other Organizations

29. *Joint Editorial Committee on Standard Methods for the Examination of Water and Sewage.* The joint editorial committee reorganized in May, 1940 with Dr. John F. Norton as chairman. The ninth edition of the text is now in preparation. It is anticipated that it will be published during 1942.

30. *Boiler Feed Water Studies.* This inter-association research committee, organized by Sheppard Powell of the A.W.W.A. more than 15 years ago, continues to render valuable service to the associations, companies and individuals having an interest in steam boilers and the preparation of water for use in boilers.

An annual review of patents in the field of boiler feed water treatment has been prepared for several years. This activity will not be continued since it appears that persons having an interest in patents incline toward the preparation of their own reference lists. The joint committee continues certain sub-committees on "Embrittlement," "Methods of Analysis," and so forth.

31. *American Co-ordinating Committee on Corrosion.* This committee is now definitely organized with F. N. Speller as Chairman and Dr. George H. Young of the Mellon Institute as Secretary. The A.W.W.A. is represented by W. F. Langelier, with H. Lloyd Nelson as alternate. During 1940, the committee issued a directory of names of persons engaged in corrosion research. This directory indicated the particular field of interest of the various individuals named. The committee plans to prepare a memorandum for the use of universities and college staffs, which would contain advice and suggestions concerning unsolved corrosion problems suitable for laboratory research.

32. *Construction Contracts.* This committee, which operates under the guidance of the Associated General Contractors of the U. S., has as its A.W.W.A. representative, L. G. Lenhardt of Detroit. The committee had developed an extended outline of the work to be done, but completion of the project has been interfered with by the defense construction program.

33. *Research Committee on Grounding.* Following the completion of a letter ballot of the Board, a memorandum concerning the present

attitude of the A.W.W.A., with relation to electric grounding practices and especially the 1940 electric code, was transmitted to the American Standards Association. The memorandum, along with certain interpretive comments by your Secretary, as well as the 1940 report of the research committee, were published in the November, 1940, issue of the JOURNAL. Since that time certain conferences have been had with H. S. Warren, Chairman of the joint research committee and with Professor Rolf Eliassen of the New York University faculty. While the production of taste, color, sediment and odor in water as a result of electric current grounding appears to be of somewhat secondary importance when the entire problem is considered, there has been much discussion concerning their production. A discussion of the questions involved has been carried on with Professor Eliassen, and it is recommended that authority be given for the initiation of research into the effects of electric current grounding, to be done in the sanitary engineering laboratory of New York University under the direction of Professor Eliassen.

34. *Water Works Terms.* This committee was organized in January, 1937, under the chairmanship of Thorndike Saville. Three associations are represented by personnel appointed to the committee. Through the good offices of the National Resources Planning Board and its Water Resources Committee, the collection, compilation and editing of a list of some two thousand terms dealing with hydrology, water works and sanitary engineering has been completed. The final tentative draft of this glossary of terms was circulated in July, 1940. The committee is now examining the possibilities of publication of the material some time during the year 1941.

35. *Water Works Accounting Manual.* Since this Association has entered into an agreement with the Municipal Finance Officers Association looking toward the eventual necessity of re-editing the *Accounting Manual*, representatives on a joint editorial committee have been appointed by the Committee on Water Works Practice. In order to develop leadership for the work, Hal F. Smith of the Detroit Water Department has been appointed chairman of the A.W.W.A. group of representatives. The others are J. C. Flanagan of the St. Paul Water Department and M. F. Hoffman of the Cincinnati Water Department.

36. *Water Hammer.* This committee was inactive during 1940.

A.W.W.A. Representatives on Committees of Other Organizations

37. *Simplified Practice Committees on Wrought-Iron and Wrought-Steel Pipe, Valves and Fittings.* This committee of the U. S. Bureau of Standards was inactive during 1940.

38. *Cast-Iron Pipe and Special Castings, Specifications for.* Three documents prepared by Committee A21, under the leadership of Thos. H. Wiggin, have been widely circulated during 1940, as follows:

A.21.1—1939 *Manual for the Computation of Strength and Thickness of Cast-Iron Pipe.*

A.21.2—1939 Specifications for Cast-Iron Pipe for Water or Other Liquids.

A.21.4—1939 Specifications for Cement-Mortar Lining for Cast-Iron Pipe and Fittings.

The A.W.W.A. has, at the request of Chairman Wiggin, made available to him and the members of his committee, preprints of a document entitled "Coal-Tar-Dip Coating for Cast-Iron Pipe and Fittings." The committee has not yet acted upon this document.

Specifications for special types of pipe (centrifugally-cast) are nearing completion.

Specifications for special castings are not yet completed and the A.W.W.A.-N.E.W.W.A. Specifications (1908) continue to be the basis of purchase in the water works field.

39. *Manhole Frames and Covers.* In 1932, a preprint of the report of this committee was published and given wide circulation. The report included a series of specifications and dimensional drawings for street manhole frames and covers. The project did not go forward to completion. It developed in the course of time that the electrical and gas utilities did not care to continue their relation to the project. This attitude was based upon certain legal questions involved, and not upon disapproval of the engineering and mechanical standards included in the proposed specifications. This left the American Society of Civil Engineers and the telephone group as sponsors for the project. Frank A. Marston represents the A.W.W.A. on the committee and William W. Brush is the representative of the American Society of Civil Engineers. Late in 1940, the specifications document was put forward for final acceptance by the American Standards Association. At the meeting of the A.S.A. Council on December 11, 1940, action upon the document was deferred, because it had been noted that since the text had been first

prepared, certain A.S.T.M. specifications for materials had been developed and approved, which affected the content of the A35 document. The matter is therefore in suspense. It gives an opportunity for the A.W.W.A. to review carefully the document as it now stands—first to see whether or not it can be approved in the light of present day circumstances and second to see whether it is necessary for the Association to appoint its own specifications committee to bring together data concerning other materials used in the water works field, such as valve boxes and covers, curb-stop boxes, meter boxes and covers, and similar water works service units.

40. *Standardization of Plumbing Equipment.* The A.W.W.A. is adequately represented in the affairs of this committee by M. Warren Cowles. His statement concerning the activities of A40 is as follows:

"Committee A40 at its meeting on April 19, 1940 received a recommendation from Sub-Committee 12 on a tentative standard for air-gaps in plumbing systems, subject to further review by the sub-committee, following the circulation of the proposed standard to some 140 members of the A.P.H.A., A.W.W.A., Conference of State Sanitary Engineers and to plumbing inspectors and others in the plumbing field; also approved tentative standard for soldered joints in copper tubing, Sub-Committee 11, for submission to members of Committee A40 for their approval by letter ballot. Other sub-committees, 1 to 10 inclusive, are virtually inactive, according to minutes of A40 Committee.

"In connection with work of Sub-Committee 12 in 1940, four meetings have been held; three in New York City (January 18, April 18 and October 28) and one in Cincinnati (June 11). At all these meetings, discussion centered upon further revision and rearrangement of the air-gap standard. At the October 28 meeting, discussion was largely centered on the replies from the requests for comments (over 100 in number) and the problems raised in the answers. The activities of the committee and the submission of comments have resulted in much broader coverage of the field from the viewpoint of water purveyors and public health supervisors, which means greater usefulness.

"Another phase of Sub-Committee 12 activity (that of preparation of a tentative standard for back-flow or back-siphonage preventers in plumbing systems) was advanced considerably by a further revision at the Cincinnati meeting. Time did not permit further discussion at the New York meeting on October 28.

"Work of Sub-Committee 12 is progressing regardless of withdrawal of A.S.S.C. as co-sponsor of A40 with the A.S.M.E. and possible resulting reorganization of A40 or its sub-committees."

41. *Pipe Thread.* Under date of February 28, 1940, there was received from Dr. John Gaillard, of the American Standards Association staff, a communication which contained the following information:

"According to the latest information received from the A.S.M.E. as one of the two joint sponsors for this project, it appears that the revision of the American Standard B2—1919, which revision has been going on for several years, may be expected to be completed shortly. At the Philadelphia meeting in December, 1939, Committee B2 practically cleaned up all pending matters and the editing committee is now expected to bring out a final draft of a revision which then will go to letter ballot of the committee. If thus approved the draft will go to the two sponsors (the A.S.M.E. and the American Gas Association) for approval, and then to the A.S.A. for final approval. As a rough guess we may assume that it will normally take from six to eight months from now until final approval by the A.S.A."

At the end of 1940 no further information upon this subject had been received.

42. *Code for Pressure Piping* and *Dimensions and Materials of Wrought Iron and Wrought Steel Pipe and Tubing, Standardization of.* Progress made by these committees during the one year, 1940, is briefly recorded by the Association's representative, H. Arthur Price, as follows:

"1. Both Committees B-31 and B-36 have been active during the year.

"2. Committee B-31 has been at work during the year on the revision of the Code for Pressure Piping originally approved and published in 1935. The last three months, the revised drafts have been in the hands of the editing committee.

"Committee B-36 has approved the revision of certain A.S.T.M. specifications for piping materials made at its June, 1940, meeting.

"3. The revision of the Code for Pressure Piping was practically completed with the meeting of Committee B-31 on December 5, 1940."

43. *National Electrical Code.* The interest of the A.W.W.A. in the activities of the National Electrical Code Committee is discussed under the heading of "American Research Committee on Grounding."

44. *Specifications for Zinc Coating of Iron and Steel.* This committee was inactive during 1940.

45. *Specifications for Sieves for Testing Purposes.* Professor Gordon M. Fair, the representative of the A.W.W.A. on this committee, reports as follows:

"The National Bureau of Standards adopted the recommendation of A.S.A. Committee Z-23 as the basis for sieve testing effective July 1, 1939, and has been using it since then.

"The A.S.T.M. adopted it as their standard last fall under the designation E11-39.

"These two organizations, as joint sponsors of the project, then recommended its adoption as A.S.A. standard. This was then adopted on December 5, 1939, as Z23.1—1939.

"Steps have been taken to have Federal Specification RR-S-366 revised to conform with the above standards."

46. *Standardization of Graphical Symbols for Use on Drawings.* W. Victor Weir who represents the A.W.W.A. in the activities of this committee has transmitted to the general chairman of the committee a copy of the A.W.W.A. recommended practice for distribution system records. This was done in order to indicate to the A.S.A. Committee the fact that the A.W.W.A. had developed standardized symbols for use in water works distribution field. In a statement, dated December 10, 1940, H. W. Samson, general chairman of A.S.A. Committee Z32 includes the following record of sub-committee activities:

"*Sub-Committee No. 1, Symbols for Mechanical Engineering.* The symbols for plumbing, piping, pipe fittings and valves, heating and ventilating, heat-power apparatus, conventional rivets, and refrigerating have been revised and completed and are now being published by A.S.M.E. for letter ballot of the sectional committee in the very near future. The welding symbols have also been completed and have been published by the American Welding Society under date of October, 1940. These symbols will likewise be submitted to the sectional committee for letter ballot in the very near future.

"*Sub-Committee No. 2, Symbols for Electrical Engineering.* The symbols for power and control have been completed and should be available for letter ballot the early part of next year (1941). The symbols for communication have likewise been completed and should be ready for letter ballot at about the

same time as the power and control symbols. I would like to point out, however, that there is still the question of certain conflicts between communication and power and control symbols to be ironed out. The symbols for architectural plans have been completed and printed by A.I.E.E. for letter ballot in the very near future. The symbols for electronics are still in the sub-group, but are rapidly nearing completion."

Committees of the National Fire Protection Association

47. *Electrical Code Committee.* Chas. F. Meyerherm represents the A.W.W.A. on this sub-committee which is studying protective grounding (*see* Section 33).

48. *Forests.* This committee has been inactive because of the resignation of its chairman. Edward E. Minor represents the Association on the committee.

49. *Hydrants, Valves and Pipe Fittings.* Frank A. Barbour represents the A.W.W.A. on the committee, the chairman of which is A. L. Brown, Chief Engineer, Associated Factory Mutual Insurance Companies. Portions of the report made by Mr. Brown at the Forty-Fourth Annual N.F.P.A. Meeting follow:

"One of the items which has appeared continuously on the report of this committee for several years has been the unification of specifications for fire hydrants, particularly those of the N.F.P.A. and the A.W.W.A.

"The A.W.W.A. at its annual meeting held this year (1940) formally accepted specifications for fire hydrants as prepared by its own Committee on Valves, Sluice Gates and Fire Hydrants. The specifications adopted are practically the same as those which they have had under consideration for more than a year, and of which a draft was distributed to the N.F.P.A. Committee on Hydrants, Valves and Pipe Fittings in January, 1939.

"The procedure of the A.W.W.A. has made it difficult for corresponding committees of that Association and the N.F.P.A. to work simultaneously on the development of a single satisfactory specification. However, by the exchange of comments on various drafts of the specifications prepared by the two associations, it has been possible to bring about reasonably close agreement, so that now with the final action taken by the A.W.W.A., it is anticipated that the N.F.P.A. specifications can

be so revised, in a few items, that the two will be in substantial agreement even though differing in form and minor detail.

"The A.W.W.A. hydrant specifications will undoubtedly be adopted by the New England Water Works Association at once."

50. *Public Water Supplies for Private Fire Protection.* C. J. Alfke, representative of the A.W.W.A. on this committee, reports no activities during 1940.

51. *Tanks.* Louis R. Howson, Chairman of the A.W.W.A. committee, represents this Association on the N.F.P.A. committee. H. A. Sweet of the Associated Factory Mutual Insurance group is a member of Mr. Howson's committee. It is believed that this interrelationship of personnel will lead to reduction of differences between the N.F.P.A. and the A.W.W.A. specifications for tanks.

Miscellaneous Committees

52. *Sulfur Cements.* This committee, organized by the A.S.T.M., has as yet developed no activity.

53. *National Association of Railroad and Utilities Commissioners' Committees on Classification of Accounts, etc.* The Association's representative was called upon for no service to this committee during 1940.

54. *Advisory Committee to the New York City Board of Health.* This committee has been called upon for no service during 1940.

New Commitments

55. *U.S.P.H.S.—Drinking Water Standards (C. R. Cox).* The U. S. Public Health Service requested the A.W.W.A. to appoint one of its members to act upon an advisory committee to the Service personnel engaged in preparation of the revision of the 1925 Treasury Standard for Drinking Water. After a careful review of the nature of the work contemplated, C. R. Cox was appointed to represent the Association. The work is in the direct charge of J. K. Hoskins, Senior Sanitary Engineer of the U.S.P.H.S.

56. *Inspection of Welded Structures (R. C. Kennedy).* This committee was organized under the auspices of the American Welding Society in 1940. R. C. Kennedy, of the East Bay Municipal Utility District, is the Association's representative on the committee. A meeting was held on October 23, 1940, at which time an outline of the project was developed. The work of the committee is now definitely under way.

No activities are current under the committee headings entitled:

Basic Water-Works Data	Reinforced Concrete Pipe
Surface Water Allocation	Asbestos-Cement Pipe
Surface Water Collection	Rates
Ground Water Collection	Water Consumption
Power and Pumping	

Respectfully submitted,
MALCOLM PIRNIE, *Chairman*,
Committee on Water Works Practice

Appendix A—Statement Re: Depreciation

By Reeves Newsom

At the annual meeting of the National Association of Railroad and Utilities Commissioners in November, 1937, a special committee on depreciation was appointed to render a report at that association's New Orleans Convention in November, 1938. This report comprised some 85 printed pages of editorial matter and tables, but was not accepted by the association as defining its policy. Instead, the committee, with some changes in personnel, was instructed to continue and it rendered another report at the 1939 Convention of the N.A.R.U.C. This report was again accepted as one of progress, and the committee, under a new chairman, Nelson Lee Smith, Chairman of the New Hampshire Public Utilities Commission, was continued, and the scope of its coverage of the subject was considerably enlarged. The committee plans a final report in December, 1941.

During the years 1938 and 1939, there was some co-operation between this special committee and representatives of the electric and gas utilities. As the life of the committee was extended and its work enlarged, the electric and gas interests undertook to provide the committee with factual data regarding the reasons for the retirements of property in those industries, broken down into several classifications, primarily for the purpose of determining the proportion of retirements resulting from physical and functional causes. That work has proceeded to the point where, during the year 1940, considerable tabulated data, representing a substantial cross-section of those utilities, were furnished to the committee. The telephone industry is in process of gathering similar information.

At about the time this depreciation committee was first appointed, I interested myself in the beginnings of the collection of data regarding the mortality survival of cast-iron pipe. This was, of course, in no way related to the work of this N.A.R.U.C. committee, of whose existence, at that time, I was not aware. Rather, it was because I had observed the arbitrary use of short lives on the part of many engineers in evaluating water works properties which, with the growing tendency towards the use of straight-line depreciation, produced heavy depreciation accruals at early age. My experience over a quarter of a century, in operating nearly fifty water works plants in several states and under various conditions, led me to believe that there was no foundation in fact for the assumption that many elements of water works properties go out of service on the average in the number of years corresponding to the lives quite commonly assigned. Having in mind that cast-iron pipe constitutes such a large part of the investment in most water systems, I studied that particular element of property first and reported, in papers presented to the conventions of the A.W.W.A. in 1939 and 1940, upon the facts found from the study of the 75-year records of the Springfield, Mass., Water Department.

Early in 1939 I had occasion to testify in a case before the New Hampshire Public Service Commission. Among other things, certain of the results of the factual studies, above referred to, were put in evidence to indicate that cast-iron pipe should be depreciated upon the basis of much longer lives than were customarily used for that purpose. This led to a series of discussions with Nelson Lee Smith about this matter and he, as Chairman of the N.A.R.U.C. Depreciation Committee, was interested in the possibility that the depreciation of water works property represented a different problem than that of electric and telephone and other short-lived property. Early in 1940, I received a letter from him asking whether or not the water works industry would be interested in furnishing to that committee some factual data which would bear on the question of whether or not the special features of water works depreciation problems were receiving proper consideration.

The A.W.W.A.'s Secretary and also the officers of the Institute of Water Supply Utilities were advised of the receipt of the letter. This latter organization of private water companies was formed during the N.R.A. code days and had continued in existence although inactive since that time. The reaction of the officers of this or-

ganization, and of the A.W.W.A. Secretary, was that, as an industry, we probably should not say no to such a suggestion and, on the other hand, we could not reply definitely in the affirmative until more was known of the aims and activities of the N.A.R.U.C. committee, and the kind, amount and form of factual data which it would like the water works industry to furnish.

Shortly thereafter, the water works representatives were invited, together with representatives of the electric, gas and telephone industries, to meet with the N.A.R.U.C. committee in July. Some progress was made at the July meeting, but the questions of the form in which the facts were to be collected and the elements of property which it would be feasible to attempt to cover were not defined until after another meeting of the N.A.R.U.C. committee was held in Washington early in November, 1940.

Following some further conferences between the sub-committee on factual data and the representatives of the Water Supply Institute, the latter organization, early in December, authorized the undertaking of the collection of retirement data from the records of the various private water companies represented. At the same time, the Institute's directors agreed to raise funds to pay the cost of necessary field work, as well as all the supervision required, on condition that the A.W.W.A. would appoint a committee which would sponsor the collection of the data from both private and public water works systems.

It seems to be generally agreed that the compilation of such data as these should be sponsored independently of the private water companies, that it should be done with regard to both private and public water plants and that while the instigating purpose may have been to furnish data for the guidance of the N.A.R.U.C. Depreciation Committee, the project should be extended in whatever way A.W.W.A. thinks proper, and that the results should become public information. At present, the latest pronouncement upon this question of lives of water works property which is considered to carry the authority of A.W.W.A. is a table in the *Manual of Water Works Practice* published in 1925. In many respects this is outdated by the present knowledge of the industry, and, often, injustice is done because there is nothing later from A.W.W.A. to amend the old figures.

The obvious difficulty in connection with this work is, of course, that of finding records covering a sufficient number of years, which

are accurate enough in detail to make it possible to establish a definite relation between the date of installation of material or equipment and the subsequent dates of retirement of the various portions of any installation, particularly when such dates are many years past. E. H. Aldrich, who has been associated with me in the studies thus far made, and I have located a few records which fulfill these requirements, some of which go back more than 100 years. A partial analysis has already been made of certain of these records. The results indicate that it will undoubtedly be possible to find sufficient data to be able, ultimately, to draw conclusions which will be satisfactorily substantiated. Such items as mains, services, hydrants and meters are used in sufficient mass to make mortality studies valuable. It is also believed that, if the field can be covered widely enough, well-founded conclusions can be drawn as to the probable lives of other elements of water works property, such as tanks and standpipes, well pumps and equipment, and certain of the more common types of pumping and filter equipment.

Useful life studies are often thought of as being of interest only to the operators of privately owned utilities. As a matter of fact, they are much more important to cities operating municipal water works plants than is often thought to be the case, and this importance is growing.

With the slackening of increase in urban population, intelligent water works management has been moving from the field of rapid and easily funded expansion programs to the field of limited expansion and planned maintenance. Long term planning for maintenance must become an essential part of good water works management, but cannot be intelligently done without knowledge of the probable useful life of various plant facilities.

With the probable loss of the tax-exemption feature of municipal water bonds, such bonds will be in a more competitive field. They will be subject to scrutiny as to the adequacy of provisions for replacement of the property as it goes out of service.

There is a growing tendency toward the use of so-called water revenue bonds, so that the water department will be completely divorced from the city's taxing power in its financial operations. This will lead to further questions as to whether the property is providing against the using up of the plant in service.

There is a spreading movement to place municipal plants under the jurisdiction of state public service commissions, first as to rates

for wholesale service to other communities and finally as to all rates and the issuance of bonds for improvements. This is the situation in some states at present. Where it obtains, value must be determined and intelligent bases for estimating the lives of the elements of plant are required in making such a determination.

Unless a body of general information is developed along the lines indicated herein, water works plants will be seriously handicapped in meeting their respective problems in these fields. It is because there is this growing need for information concerning the *useful life* of water works structures that the recommendations are made that the A.W.W.A. co-operate with the N.A.R.U.C. in the collection of data concerning life of water works structures, and that the co-operation in sponsorship be obtained from the New England Water Works Association.

Appendix B—Action by the Board

Following the presentation of the above report, the following action was taken by the Board of Directors:

The Manual of Water Quality and Treatment was ordered reprinted.

The Board expressed appreciation of the interest of M. N. Baker in the preparation of a "History of Water Treatment." It agreed to the suggestion that the text be planned not to exceed 400 printed pages and, if possible, that it be available for publication during 1941. A budget was set up to cover editorial and publication expenses.

The name of the Committee on Chemical Hazards in Water Works Plants was changed to "Safe Handling of Water Works Chemicals."

The Secretary was directed to convey a formal invitation from the Board of Directors to the New England Water Works Association that it consider the adoption of the "Specifications for Steel Standpipes and Elevated Tanks," which have already been tentatively adopted by the A.W.W.A. and the American Welding Society.

A committee to develop data on "Useful Life of Water Works Equipment and Structures" was authorized. Louis R. Howson was appointed chairman of the committee. A budget was set up to cover the Association's share of the necessary expenses of the committee during the year 1941. The Board directed the Secretary to convey

to the New England Water Works Association an invitation to participate in the work of this committee.

The establishment of a "Committee on Water Purification Practice" by the Water Purification Division was authorized. It was understood that a member of this committee would also be appointed to membership on the Committee on Water Works Practice.

The editorial handling of "Specifications for Water Works Chemicals" by the office staff was approved.

The Board directed that the Committee on Chloramination be requested to have a report ready for consideration by the Water Works Practice Committee by May 15, 1941.

The Board authorized the establishment of a research project in New York University for the purpose of investigating the effects of grounded or stray alternating current on water service lines or the water conveyed by them. A budget was set up for the expense of this work.

The Board approved the establishment of an A.W.W.A. committee on "Minimum Recommended Standards for Valve Boxes and Covers, Curb Stop Boxes and Covers and Meter Boxes and Covers."

HARRY E. JORDAN, *Secretary*

Errata

1. The titles of photographs on pages 53 and 60 of the January, 1941, JOURNAL should be interchanged, the illustration on page 53 being a section of 30-inch main and that on page 60, a 4-inch main.

2. Page 84, line 17, *Ibid.*: *for* "—not an elected official—" read "—and an elected official—."

ABSTRACTS OF WATER WORKS LITERATURE

Key. 31: 481 (Mar. '39) indicates volume 31, page 481, issue dated March 1939. If the publication is paged by issues, **31:** 3: 481 (Mar. '39) indicates volume 31, number 3, page 481. Material enclosed in starred brackets ★[ ]★ is comment or opinion of abstractor. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; P. H. E. A.—Public Health Engineering Abstracts; W. P. R.—Water Pollution Research (British); I. M.—Institute of Metals (British).*

BOILERS AND FEED WATER

The Circulation of Water and Steam in Water-Tube Boilers, and the Rational Simplification of Boiler Design. W. Y. Lewis and S. A. Robertson. Proc. Inst. Mech. Engrs. (Br.) **143:** 3 (June '40). Authors stress need for sound theory of circulation in water-tube boilers to enable weight and space to be saved and efficiency and reliability to be increased. They establish, as a standard of excellence with which other boilers may be compared, a simple boiler consisting of a single drum and a single U-tube. Paper consists of 3 parts —Part 1 describes nature of change from water to steam; Part 2, calculation of flow in simple U-tube boiler; and Part 3, features of various departures from standard U-tube met with in practice. Improved type of tube, approaching very nearly to standard U-tube, is evolved, allowing much simplification of boiler design, with advantages of excellent circulation, high gas speeds, and higher heat transmission rates. Other rational simplifications and improvements which enable substantial reductions to be made in cost of manufacturing, installing, and maintaining boilers of any pressure and capacity, for any service, ashore or afloat are also made possible. Authors go into complete details showing theories, reasons, experiments, and results with sound and logical approach to conclusions reached. Entire article revolves around simple U-tube as ideal instrument for boiler heat transfer and steam generation. From theory of circulation it is reasonable to conclude that, so far as circulation is concerned, simple U-tube boiler will give satisfactory results over a very wide range of pressures and rates of heating. Long experience with boilers which approach most nearly to this standard U-tube boiler with unheated downcomers, therefore, points it out as a standard of excellence, in its ample flow under natural head, its ability to absorb intense heat, its assurance against any interruption which might lead to overheating, and in its simplicity of design. Study of common variations from U-tube standard shows that these departures frequently diminish performance of tube considerably, especially at high furnace temps. and working pressures now becoming common. Simplified form of boiler has been evolved which seems as near to standard as possible, having unheated downcomers, individual water supply to each tube, free discharge for steam, and ample circulation under natural head for a wide range of pressures and intensities of heating. Moreover, numerous external advantages accrue from use of this rational design, such as freedom from longitudinal temp. stresses; ease of soot cleaning; ease of arranging correct area of gas passages; considerable reduction

in size and complexity by the elimination of bottom drums and headers; overall reduction in size owing to possibility of using more intense heating rates with safety, especially in rear tubes; and very great economies due to eliminating need for external economizer. This form of water-tube boiler would appear to be valuable advance in boiler technique, and to afford best means for increasing safety and reducing capital, maintenance and housing costs of boiler plant; of reducing boiler weight, work, and space on ships, and of improving reliability by reducing frequency and duration of shut-down periods for cleaning and repairs, especially in base-load electric power stations, wherein this desideratum has recently proved to be of urgent importance.—*Homer Rupard.*

Steam Superheaters for Water Tube Boilers. C. B. CHARLEWOOD. Eng. Jour. (Can.) **23:** 344 (Aug. '40). Article is text on design, installation and operating features of superheaters, in terms of principal use to those engaged in design and application problems. Following section on economic advantage of superheated steam is of general interest:

"Superheated steam, due to its relatively higher specific volume, shows largest thermodynamic gain when applied to reciprocating engines, effect being equivalent to reducing percentage cutoff. Incidental advantages are reduction of heat lost through cylinder walls by conduction, and saving in lubricating oil, which is not washed away to same extent as with saturated steam. As an approximate rule, each 1% of moisture in steam at cutoff will reduce engine efficiency by 2%. About 8°F. of superheat is required to eliminate 1% of moisture in steam at this stage. Engines originally designed for use with saturated steam will in most cases operate satisfactorily at temps. up to 500°F. Beyond this temp. some difficulties may be experienced with cylinder lubrication, gland packings, and expansion stresses in piping. On other hand, suitably designed reciprocating engines, notably in locomotive work, have operated at steam temps. of 850°F. with perfect satisfaction. As applied to steam turbines, superheat results in actual gains considerably greater than theoretical. Principally due to reduced frictional or windage losses within machine, and reduction of moisture at exhaust end. In general each 10°F. of initial superheat will decrease blade and nozzle losses approx. 1%. With more than 10% moisture in turbine exhaust, pitting and erosion of blading is probable, with rapid falling off in efficiency of low pressure stages. In consequence, initial superheat is largely determined with reference to steam conditions at exhaust."—*Homer Rupard.*

Complex Silicate Scales in High-Pressure Boilers—Their Occurrence and Correction. S. T. POWELL, L. V. CARPENTER AND J. J. COATES. Combustion. **11:** 2: 18 ('39). In low pressure boilers, silica scales are not formed if calcium and magnesium have been removed from feed water, but in high pressure boilers hard scales, consisting of complex silicates, are formed even in their absence. No form of internal treatment is completely successful in prevention of silica scale and it is necessary to reduce amount of silica in feed water as much as possible. All natural waters contain some form of silica, largely derived from weathering of rocks. Content of silica tends to be higher in soft than in hard waters. Stumper has concluded that most of silica in water is in true solution and that only from 2.5 to 20% is present as colloidal dispersion. Form in which silicic acid exists in solution depends on pH value of solution. In acid waters it tends to form colloidal polysilicic acids, and in alkaline waters there is an equilibrium between mono- and disilicic acids. In theory it should be possible to remove silica from water by condensing mono- and disilicic acids to colloidal polysilicic form, or by precipitating them as insoluble silicates. Formation of silica scales can be prevented to a certain extent by internal treatment with compounds of iron or sodium phosphates, or organic materials. Stumper found that to remove silica from feed water, sodium, barium, and calcium aluminates were most effective reagents.

Addition of 200 p.p.m. sodium aluminate reduced the content of silica to 0.5 p.p.m. Stumper considered that removal was largely due to adsorption. Ferric compounds are now used at several plants. In recent experiments addition of a solution containing ferric sulfate and sulfuric acid followed by addition of alkali to raise the pH value to above 7.5 has reduced concentration of silica from 2-3 to 0.5 p.p.m. Magnesium oxide with caustic soda and alumina, and magnesium sulfate with sodium aluminate have also been used. Silica scales have recently been examined by petrographical methods and presence of analcite (a double silicate of sodium and aluminum), which closely resembles the analcite found in certain volcanic formations, has been detected. Plants suitable for treating boiler feed water for removal of silica are described, including tanks in which water is brought into repeated contact with the precipitated sludge. Flow diagrams of two plants are included.—*W. P. R.*

Salt and Silica Deposits in Steam Turbines. H. GOERKE. Elektrizitätswirtschaft (Ger.). **38:** 614 ('39). Deposits of salt on turbine blades form rapidly at high pressures. At pressures below 40 atm. they form slowly and are removed in periodic overhauling. At pressures of up to 40 atm. composition of deposits varies widely; hardness-forming substances, soluble boiler salts and rust are included. At higher pressures sodium chloride is chief soluble constituent, others being sodium hydroxide, sodium silicate, sodium carbonate and sodium sulfate. Silicic acid is commonest insoluble compound and calcium carbonate may occur. The more soluble salts are deposited at higher temp. than the others. Chief cause of deposits is presence of sodium hydroxide in boiler water. Boiler water should not contain more than 10–25 mg. sodium hydroxide per liter and concentration of silica should not exceed 5–10 mg. per liter. Data for 10 turbines operating at pressures between 68 and 130 atm. show that, using water treated with chemicals, salt deposits occurred at 68 atm. and silicate deposits at all higher temps. When condensate was used, a salt scale appeared on 1 turbine operating at 125 atm. With increase in temp. of steam, content of free silicic acid in deposit increased and that of sodium silicate decreased. Salt deposits can be removed by saturated or nearly saturated steam. Sodium hydroxide solutions and low pressure steam are used for removing silicate deposits.—*W. P. R.*

Silica in Boiler Feedwater. WILLIAM F. PETERS, JR. AND W. D. TURNER. Power Plant Eng. **44:** 3: 54 (Mar. '40). Because silica is soluble in alkali, softening (which generally occurs at pH 11) does not remove it. Under 6.2 it is insoluble. No softening method seems very effective. Some organic materials have silica-removal properties. *Ibid.* **44:** 4: 47 (Apr. '40). Procedure is outlined based on preference of silica and Al compounds to combine with Mg at not too high pH values. In procedure, 3 p.p.m. $MgSO_4$ to 1 p.p.m. SiO_2 is suggested. pH must be held at 10.6.—*C. A.*

Removal of Silica from Water. A. S. BEHRMAN AND H. GUSTAFSON. Ind. Eng. Chem. **32:** 468 (Apr. '40). Although sodium silicate was used in boiler compounds less than 20 yr. ago, at present silica in boiler feed waters is reduced to minimum since in present-day high-pressure boilers, silica scale would cause local overheating and tube failure. Silica removal is frequently combined with water softening. Use of ferric sulfate for silica removal necessitates two-stage softening for proper pH control of silica removal process, chemical dosages and consequently costs are relatively high, and dissolved solids of boiler feed water are considerably increased. Sodium aluminate also requires relatively large chemical dosages and pH control, though efficiency is higher than in ferric sulfate method, and dissolved solids are not unduly increased. Gels of oxides of iron and aluminum have silica removal powers when used as solid granular particles in an adsorbent bed

through which the water is percolated. Adsorbent may be regenerated by acid, alkali or both. Obstacles to their use are difficulty and cost of preparing them, and their sensitivity to regenerating agents. Granular activated alumina has silica-removing properties and can be effectively regenerated by strong acid followed by alkali. In lime-soda softening, pptn. of calcium as $CaCO_3$ removes little silica; silica removal is proportional to magnesium pptd. If water contains too little Mg to adsorb all of silica, soluble Mg can be added. Advantages over ferric sulfate method are: (1) single-stage softening at as high a pH as desired, combined with silica removal (2) lower chemical costs, and (3) less increase in dissolved solids. Magnesium carbonate or bicarbonate can be used as source of Mg, thus avoiding increase in dissolved salts (as when the sulfate is used) and allowing use of lime alone without soda ash. Needed Mg is best introduced by adding carbon dioxide to water to be treated and then passing water through bed of magnesium oxide or carbonate, *e.g.*, calcined magnesite or granular activated magnesia. Dolomitic lime as a source of Mg is not satisfactory; apparently $Mg(OH)_2$ to be effective in silica removal must be formed *in situ*. Best results in silica removal with Mg are achieved in equipment providing intimate contact of water with large quantities of previously pptd. sludge. Although present techniques of silica removal permit reduction of silica content almost as wished, so much is to be desired in some cases that there is room for considerable progress.—*Selma Gottlieb.*

The Preparation of Feed Water Free of Silicic Acid and Hardness. W. WESLEY. Chem. Fabrik (Ger.) ('40) p. 85. Pilot-plant-scale expts. on prepn., of H_2O for high-pressure boilers are reported. Steps in process are: removing CO_2 and SiO_2 by mixture of CaO and MgO at 97°, filtering, treating with SiO_2, exchange softening with synthetic resin, "Wolfatite" ("P-resin"), and addn. of NH_4 phosphate. Flow-sheet is shown, each step described and results tabulated.—*C. A.*

Silicic Acid and Its Significance in the Operation of High-Pressure Boilers. A. SPLITTGERBER. Mitt. Ver. Grosskesselbesitzer. (Ger.) **73:** 206 ('40); Wass. u Abwass (Ger.) **38:** 58 ('40). Amount of silicic acid in water ranges from a few mg. to about 50 mg. per liter. In most cases, proportion of silicic acid to total ash is less than 1:10, but may be up to 5 times this amt. Not clear whether silicic acid is present as colloid or as constituent of clay. Can enter water from decomposition of glass, filter sand, and base-exchange materials. Details of methods of deposition in boilers and of solubility of calcium and magnesium silicates are given. Solubility decreases with increasing temp. so that silicate scale will be deposited in boilers unless deposition as a sludge is ensured, for example by addition of phosphate. After discussing volatility of silicic acid with superheated steam and deposition of silica in turbines, methods of removing silica from water are considered. Lime does not completely remove silica unless used with magnesia. Filtration through magnesite with acid reaction is effective. In some plants, silicic acid almost entirely adsorbed, after thermal softening of water, by addition of caustic soda and suspension of magnesia. Removal by aluminum sulfate leads to difficulties with increased concentration of this salt in water. Addition of sodium aluminate is fairly effective. Iron salts, especially ferric sulfate, are better than aluminum salts. Satisfactory removal can be achieved by treatment with magnesia and iron or aluminum compounds. Electrolytically-produced flocculating agents are also effective. After discussing influence of silicate on embrittlement, reference is made to general use of sodium silicate in England and America for production of protective layers in hot water plants. Comprehensive review of literature.—*W. P. R.*

Method for Analysis of Boiler Scales and Sludges. F. K. LINDSAY AND R. G. BIELENBERG. Ind. Eng. Chem.—Anal. Ed. **12:** 460 (Aug. '40). Colorimetric and turbidimetric procedures used with a "Phototester" save considerable time

in boiler scale analysis. Results check well, and in ⅓ to ½ the time, with gravimetric methods involving reprecipitation of constituents sought. In boiler scale analysis, rapidly and conveniently obtained knowledge of type of deposit involved is more important than great accuracy. 40-mg. dried sample is heated to 1000° for detn. of loss on ignition, fused with K_2CO_3, dissolved in HCl, neutralized and made up to 100 ml. Aliquots are used for detn. of iron oxide with ferrous thioglycolate, P_2O_5, by reduction of phosphomolybdate, SiO_2, by reduction of silicomolybdate and aliquots of a 1:10 dilution for detn. of calcium oxide with Na sulforicinoleate, magnesium oxide with titan yellow, sulfur trioxide with barium sulfate, and aluminum oxide with aurin tricarboxylic acid. Readings in above tests are made with "Phototester," a photoelectric colorimeter ruggedly designed for portability, and powered with flashlight batteries, though storage batteries or a bell-ringing transformer may be attached. Wooden carrying case contains space for extra test bottles, calibration curves and some reagents. Can be used in field or lab. Measures decrease in light transmission and therefore current generation in circuit containing photoelectric cell due to color or turbidity of liquid being tested. In addition to above tests, carbon dioxide is detd. gravimetrically on separate sample by liberation with HCl and absorption in ascarite.—*Selma Gottlieb.*

Composition of Boiler Scale in Relation to the Quality of Boiler Feed Water. INOSUKE WATANABE. Trans. Soc. Mech. Engrs. (Japan) **4:** 14: 57 ('38). Analyses of boiler feed waters in Manchuria and of boiler scales which are formed from these various kinds of water given. Structure of scale and relation of structure to scale compn. are considered. Author believes SiO_2 in water has much influence upon formation of boiler scale and corrosion. Scales in superheater tubes of locomotive condenser tube, water softeners and corrosion of locomotive boiler plate are also presented for reference.—*C. A.*

X-Ray Method of Identifying Types of Scale-Forming Deposits. P. E. FITZGERALD. Petroleum Engr. **11:** 7: 161 ('40). X-rays can be used to identify the many types of scale which deposit in heat exchangers, condensers, etc., to permit more rapid selection of solvent best suited for removal of the scale. If deposit forms no pattern, x-ray method is of no use, but only 5% of inorg. solids fail to develop pattern. Analysis is made as follows: Powd. sample of deposit is placed for a distance of about 1 cm. on each side of a cotton plug placed in the center of pyrex capillary tube. Cotton plugs are then placed at each end of tube, and tube is sealed in a flame. Sealed tube is then inserted in camera and whole assembly is placed on diffraction unit and exposed for 6 hr. at 30,000 v. and 20 milliamps. Each camera is equipped with small elec. motor to turn sample during exposure. Some units hold as many as 12 cameras, each contg. tube holding 2 specimens; this makes possible simultaneous exposure of 24 specimens. At present, x-ray diffraction allows detn. within 5% of amt. present. Advantages are discussed. X-ray patterns of typical scales given.—*C. A.*

Scale Removal by Chemical Means. M. E. BRINES. Power Plant Eng. **44:** 46 (May '40). Usual base for most of industrial solvents used by Dowell, Inc. is an inhibited muriatic acid. Inhibitors, catalysts, wetting agents, intensifiers and reaction control agents are added to facilitate results and protect exposed metal surfaces. Section of auxiliary chemicals depends on composition of scale to be removed and of metals to be protected. "X-Ray Powder Diffraction" patterns are used to determine approximate concentrations of actual chemical compounds present. Only a few milligrams of scale are required for analysis to determine composition of complex substances which cannot be detected by quantitative analysis. Value of this method depends on completeness of reference file of known compounds. Following equipment pieces have been successfully treated: boilers, heat exchangers, economizers,

superheaters, water softeners, filters, hot-water lines, sewers, condensers, turbine blades, and cooling systems on air compressors and internal combustion engines. "Pickling" of new equipment for removal of scale from fabrication and erection is another phase of application. —*T. E. Larson.*

Combating Scale by Means of Boiler Compounds. P. I. VOLKOV. Chimie & Industrie. (Fr.) **43:** 207 ('39). Most generally used products contain one or more of following: Na_3PO_4, Na_2CO_3, NaOH, Na_2CrO_4, oak extract, starch and linseed. Oak extract acts by formation of protective Fe tannate film which covers inner surface of boiler. Starch disintegrates scale which has formed, but mechanism of action is not known. Potatoes, sugar and petroleum act similarly. Best results are obtained by use of small amts. of several of these products.—*C. A.*

Influence of Copper With Respect to Corrosion in Boilers. F. R. OWENS. Combustion. **11:** 11: 41 ('40). Source of Cu deposits in boilers is attributed to surface condensers and closed heaters. In most cases where Cu has been found in feed water with resulting deposition in boilers, general opinion has been that loss of Cu at condensers has been due primarily to NH_3 in condensate. Not the only factor, however. In many instances loss of Cu in condensing equipment is largely due to oxidation and subsequent action of weak acids, such as H_2CO_3. In some cases possible to eliminate Cu losses in closed heaters by decreasing H-ion concn. of feed water. In general, however, there are very definite limitations with respect to chem. means of preventing Cu losses at surface condensers and to a lesser extent at closed heaters. Best means available should be resorted to for de-aeration; this is essential not only from viewpoint of O_2 removal, but for CO_2 and NH_3 as well. Any changes in chem. treatment which tend to establish elec. neutrality should be tried. Excessive heat input to local areas within boiler, with resultant dry areas, should be corrected. Need for research in field emphasized.—*W. P. R.*

Review of Progress in Feed-Water Treatment. C. H. FELLOWS. Mech. Eng. **62:** 392 ('40). Chief objects in treatment of feed water are prevention of scale on heating surfaces, control of corrosion, prevention of carry-over to avoid formation of deposits in superheaters and on turbine blades, and prevention of caustic embrittlement. In early days of steam boilers, corrosion did not cause much trouble as so much mud and scale accumulated in boiler that water never came into contact with metal. As operating pressures were increased and became necessary to reduce concentration of dissolved salts and suspended matter to avoid foaming and carry-over, amount of scale and mud was reduced and corrosion began to occur. At present, oxygen is regarded as chief cause of corrosion in boiler. Caustic embrittlement has never been fully understood; has not yet been observed in modern high pressure boilers. In nearly every case, primary reason for treating boiler feed water is to prevent formation of hard scale in boiler. Treatment with sodium carbonate or phosphates, softening by base-exchange or lime-soda, addition of colloids, or electrolytic treatment may be used for prevention of scale formation. Some of these processes also assist in prevention of corrosion. Removal of dissolved oxygen is of primary importance in control of corrosion. De-aeration is most common method used, but always danger that oxygen will be introduced to system after de-aeration. To avoid this, substances which will react with oxygen may be added to water, *e.g.* sodium sulfite, colloidal iron, or organic materials. Corrosion by carbon dioxide can be prevented by adding highly ionized acids and then de-aerating. Corrosion in certain parts of boiler may be due to lack of proper circulation; best avoided by improving design. None of remedies for caustic embrittlement so far tried seems to be infallible, though sodium sulfate, lignin, or sodium chloride in presence of sulfate ions may be beneficial. Physical state of precipitated solids is important factor in control of carry-over. Straub has suggested that sodium sulfate should be

added to counteract sticky quality of sodium hydroxide deposits and to prevent formation of deposits on turbine blades. Treatment of feed water also depends on conditions of operation. When little make-up water is used, should be little danger of scale formation. If pH value is below 10.5–11; may be necessary to add alkali to prevent corrosion. If phosphates are added at same time caustic embrittlement should be prevented. Treatment might be combined with removal of scale-forming constituents. Concentration of dissolved salts in boiler should be maintained at minimum. Results will be improved if solids are flocculated by addition of coagulant. In high-pressure boilers addition of sufficient sulfate to maintain a sulfate-alkalinity ratio considered high enough for control of caustic embrittlement will produce high concentrations of salts and cause carry-over. In cases where ratios have not been maintained, embrittlement has not occurred. May be due to welded construction of high-pressure boilers, which reduces stress and avoids seams and crevices. —*W. P. R.*

Glucosides and Glucosates in Boiler Feed Water Treatment. C. H. S. Tupholme. Eng. & Boiler House Rev. **52:** 376 ('38). Properties of a no. of glucosides and glucosates used to control scale and corrosion in boilers are described. β-Glucoside adsorbs gases such as CO_2 and H_2S and reacts with O to form stable oxidation product which, with β-glucoside, removes metallic ions in form of an insol., hydrophilic gel which settles slowly, preventing deposition of scale in pipe lines. Water treated with β-glucoside boils evenly; foaming is inhibited and oil and silica are removed. Na glucosate reacts with CO_2 and O, will remove silica or Na silicate scales and may be used, over a range of pressures of 15 to 400 lb. per sq.in., to increase pH value and inhibit corrosion without causing deposits in feed lines. Pyroglucosate is an org. phosphate stable at high temps. and pressures. Used to prevent formation of scales of Ca sulfate and silica and inhibits corrosion by formation of unimolecular film on boiler surface. Alky. in treated water rarely exceeds 100 p.p.m., and total alky. is usually <300 p.p.m. Phosphoglucosate is strongly acid and reduces alky. of water; used, usually with chrome glucosate, to prevent corrosion. Na phosphoglucosate is also used for this purpose. Phosphoglucosate forms gels with Ca and Mg ions but forms heavier sludge which is more readily deposited than sludge formed by other glucosates. Chrome glucosate removes rust and products of corrosion, forms protective, impervious, adherent film over metal surface and is effective over a pH range of 6–12. It is used in air-conditioning systems, pasteurizers, cooling towers, condensers, brine systems and internal combustion engines, but is unsuitable for treating drinking water. Sulfo-glucosate removes O from water more readily than Na_2SO_3; does not affect quality of drinking water and does not precipitate sulfate scales.—*W. P. R.*

Sulfur Burner Applied to Feed-Water Treatment. S. T. Powell, G. A. Cain and J. B. Chatelain. Power Plant Eng. **44:** 54 (May '40). Hoskins Mound Mine of Freeport Sulfur Co. employs sulfur burner to produce SO_2 for use in feed-water treatment for sulfate-alkalinity ratio adjustment and for chemical de-aeration. Reaction of dissolved oxygen in softened feed water with sulfite produced is catalyzed by .01 to .025 p.p.m. copper. Advantages listed for installation include savings of $5.50 per 10^6 gal. for sulfate alkalinity ratio adjustment, $1.50 per 10^6 gal. for de-aeration and cost of handling 620 lb. chemicals. Dissolved solids in treated water are not appreciably increased as by former treatment. Feed-line deposits are reduced by resultant lower pH.—*T. E. Larson.*

Phosphate Treatment of Boiler Feed Water. G. Ammer. Wärme. (Ger.) **61:** 188 ('38); Chem. Zentr. (Ger.) **II:** 910 ('38). Phosphate sludge formed as result of its very slight solubility in treatment of such waters with phosphate represents a hydroxylapatite with a

molecular ratio P_2O_5:CaO of 1:3.3. This gives theoretical consumption of 36.9 grams trisodium phosphate per German degree of hardness per cu. m. in addn. to a phosphate excess. In combination with recirculation of boiler water with utilization of NaOH formed in boiler for presoftening, this amt. can be still further reduced depending on ratio of carbonate to noncarbonate hardness, degree of dissociation of soda, total salt content, and amt. of recirculated boiler water.—*C. A.*

Intercrystalline Cracks in Locomotive Boilers. W. C. SCHROEDER, A. A. BERK AND R. A. O'BRIEN. Railway Age. **109:** 1: 25 (July '40). Elimination of riveted areas and use of welded drums in power plant boilers removes possibility of slight seam leaks which are necessary for intercrystalline cracking, but practice is not yet permitted in locomotive boiler construction. Three factors combine to produce intercrystalline cracks in boiler: (1) leakage that allows concentrations of boiler water; (2) high stress in boiler metal arising either from cold work or applied stress; and (3) chemical action of concentrated boiler water on stressed steel. Small device, called "Embrittlement Detector," has been designed and can be installed on outside firebox sheet of locomotive, to demonstrate embrittlement tendency of water by action on a stressed specimen in a 30-day period. Best means for embrittlement prevention is proper boiler construction with absence of leakage. Due to many old locomotives, in service with questionable riveted seams, some protective chemical treatment of the water is advisable. Railroad experience and records indicate that Na_2SO_4, sometimes recommended for purpose, is of no benefit in locomotive service. Waste sulfite liquor has shown promising results in lab. tests and is being extensively used on several railroads with apparently good results. Other means are under investigation, as well as effect of different types of alloy steels.—*R. C. Bardwell.*

TREATMENT—GENERAL

Water Treatment. JACK GORDON. Am. City. **55:** 8: 59 (Aug. '40). At Rochester, Ind., two 26″ gravel-packed wells, each 100′ deep, supply 800 g.p.m. containing 16 g.p.g. hardness and 2.6 p.p.m. of iron. In '39, work started on treatment plant to involve: (1) aeration, followed by settling and filtration; (2) softening $\frac{4}{5}$ of water by use of zeolite; and (3), mixing softened water with $\frac{1}{5}$ of hard but iron-free water. Operation costs have been satisfactory and finished water is now supplied with hardness of 3 g.p.g. and iron content of about 0.1 p.p.m.—*Arthur P. Miller.*

Water Treatment. WALTER W. GRAF. Am. City. **55:** 9: 54 (Sept. '40). In '32, Lancaster, Ohio, constructed its water-softening and iron-removal plant but only 2 of 3 proposed units were completed. Increased demand brought completion of 3rd unit in '39. Well pumps discharge to 2-unit "aer-o-mix" where 50% of CO_2 is removed and all iron oxidized and sufficiently precipitated to be removed by 3 conventional sand filter units. Following filtration, 3 zeolite softeners function. Regeneration process is described. Chlorine is applied between softeners and clear well, and soda ash, for pH control, at same point. Ave. hardness is reduced from 21.2 to 4.2 g.p.g. and water is free of iron.—*Arthur P. Miller.*

Purification of Water in the Principal Water Supplies in Belgium. L. JANSEN. Rev. Univ. Min. (Fr.) **15:** 554 ('39) (*Epuration des Eaux I.*). *Antwerp:* Water works at Antwerp draw their supplies from River Néthe. Increased population of Brussels and development of industry have caused pollution of river. There are 2 water works, at Notmeir and Waelhem. As river is tidal, water is drawn at low tide, and discharged into 1 of 3 preliminary sedimentation basins (each with capac. of $\frac{1}{2}$ daily demand) at Notmeir. Aluminum sulfate, as coagulant, and copper sulfate are added to reduce development

of algae. Water is aerated, filtered, and stored for a week in open reservoir where self-purification takes place. It is then pumped to Walhem works where it is filtered through 24 slow sand filters. Filtered water contains about 10 bacteria per ml., no coliform organisms and only 40 mg. of organic matter per liter. Water is stored in res. near Antwerp, where it is chlorinated. *Malines:* Water supply is drawn partly from Hofstade lakes, and partly from River Dyle. Has hardness of 20° (Fr.) and is softened by lime and soda ash to total hardness of 6° (Fr.). 12,000 cm. per day of this water are used by railway, and 4,000 cm. per day for supply of Malines. Latter portion is further treated by slow sand filtration. *Malmédy:* Draws its water from Warche reservoir. At first water was treated with ozone, but this caused heavy precipitation of iron oxide in summer, and now is only used in winter. In summer, water is treated with lime and aluminum sulfate, and is then filtered and chlorinated. When necessary, chlorine is added before filtration and excess chlorine is removed by addition of active carbon. Filtered water has no taste or color; original pH of 5 is raised to 8; bacterial count is 5 per ml., and there are no coliform organisms. *Liège:* Most of the water supply comes from Hesbaye, and remainder from gravels of bed of Meuse. Water from Meuse is treated for removal of iron and manganese and is sterilized. *Brussels:* Part of water supply is treated by ammonia-chlorine process. *Knocke:* Except for locality served by "Intercommunale des Flandres," water supply for Knocke and other sea-side resorts is drawn from wells under dunes. Raw water is soft, contains iron, and is often contaminated in summer, when population is greatly increased. Water supply of Knocke is treated in 2 plants, each treating 200 cm. per hr. Concentration of iron is reduced from 0.2–1.2 mg. per liter to less than 0.1 mg. per liter by aeration and filtration through open sand beds; 0.2 mg. per liter chlorine is added after filtration. *Brée:* Water is drawn from wells in the gravel of Meuse. Raw water is soft and contains free carbon dioxide. It is treated in limestone filters. Hardness is thus increased from 7.9 to 13.5° (Fr.), pH is raised from 4.7 to 7.1, and free carbon dioxide is reduced from 69 mg. to 12 mg. per liter. *Charbonnages d'Hensies-Pommeroeul:* Water is drawn from polluted Mons-Condé canal, treated with lime, aluminum sulfate and chlorine, and filtered through sand and active carbon. Filtered water contains no bacteria. *Discussion.* DUSSERT: Pointed out that problem in sterilization was to destroy bacteria without affecting desirable qualities in water. In chlorination, difficulty is often experienced in controlling excess chlorine in treated water. Many French towns now use ozone, as sterilization takes place in shorter time. Ozone removes odor and color, and process is not expensive. Excess ozone can be used with no dangerous products remaining in water. DE LIPKOWSKI: Described works at Roncq, which supply water for industries of towns of Roubaix-Tourcoing. Water is drawn from river heavily polluted with industrial effluents. Results of analyses of samples taken from various points are given in tabular form. Following method of treatment has been found satisfactory: Water is settled for 2 hr., then treated with ferric sulfate and a hypochlorite in 2 coagulation tanks, with detention periods of 1 hr. and ½ hr. It is passed through filter at 10 cm. per sq.m. per hr., and through a second filter at 5 cm. per sq.m. per hr.—*W. P. R.*

Water Purification by Supersonics. H. BEUTHE, E. FURBACH AND C. SÖRENSEN. Akust. Zeit. (Ger.) **4:** 209 ('39); Phys. Ber. (Ger.) **21:** 15 ('40). Investigations were carried out to determine whether water could be purified commercially by means of supersonic waves. Carbonate hardness of tap water was reduced by waves, but non-carbonate hardness changed only slightly. If 75% soln. of gypsum is treated with supersonic waves, transparency of solution is decreased. Effect is increased if soln. has previously been saturated with oxygen. Reduction in carbonate hardness in tap water may be due to heating action of waves, but precipitation from solns. of gypsum must be due to chem. action as shown by effect on reaction of

concentration to oxygen. Supersonic waves did not appear to have any coagulating action. Optimum energy was about 0.09 watt per gram of soln.; higher values led to decrease in chem. action.—*W. P. R.*

High Speed Water Purification Plant. W. W. DeBerard. Eng. News-Rec. **123:** 342 (Sept. 14, '39). Water supply for Lakeside plant of Springfield, Ill., is derived from Lake Springfield, 22-billion gal. artificial res. Shores have been developed by city for residential and recreational use. Sewers lead out of watershed. Swimming area, located 2 mi. across lake from water works intake, is enclosed by permeable sheetpile dike. Low-lift circulating pump, taking suction outside dike, discharges into perforated pipe laid in gravel-filled trench near shoreline of beach and circulated water is chlorinated. No pollution has been observed from this source. Boating is encouraged. Purification plant is equipped with Spaulding precipitators, sludge from which is concentrated, dried and hauled away by farmers for lime content. Sand in 4 filters has effective size of 1 mm. Washing procedure consists of draining filter to few inches below sand surface, breaking surface for 2–3 min. with spray from nozzle under 100-lb. pressure, and backwashing 3–4 min. at rate of 45″ vertical rise per min. Sand surface is within 8″ of overflow weir and there are no wash water troughs. Units washed regularly at 48-hr. intervals. Normal rate of filtration is 4 gal. per sq.ft. per min.: rate 67% in excess of this has been employed. Rate of 5 gal. per sq.ft. per min. is considered entirely safe and productive of zero turbidity and high bacterial removal. In '38–'39, ave. coliform bacteria content of city tap water was 0.04 per 100 ml.: lake water ave. was 27. Hardness is reduced from 168 to 84 p.p.m. Cost of softening and purification averaged $13.73 per mil. gal. sold in '38.—*R. E. Thompson.*

Treating Water of High Color. Anon. Am. City. **55:** 11: 60 (Nov. '40). Water for New Canaan filtration plant at Norwalk, Conn., comes from Grupe Res. which in turn is served by Scotts and Brown Res. Typical New England water, with color varying from 22 to 70 and alkalinity of 20 to 6 in times of low and high water respectively. As there are a no. of consumers on main line from res. to filter plant, water is chlorinated as it leaves Grupe Res. At plant, arrangements and devices permit aeration, chem. mixing with stirring paddles and baffles, settling (4 hr. at 5-m.g.d. rate), and filtration in two 1½-m.g.d. rapid sand filters. All gage and meter equipment, except that for individual filter units, is on one panel; and almost all operations can be controlled from within bldg. Interesting feature of settling basin is that first third of each basin is underdrained by 6″ tile lines made up of 6″ x 4″ tees with 4″ hub set flush with floor and provided with tile plugs having 1″ orifices. Using system for periodic flushing reduces necessity for periodic emptying of basins for cleaning.—*Arthur P. Miller.*

Automatic Control of Treatment for Well Water. Bayard F. Snow. Am. City. **55:** 9: 41 (Sept. '40). About half of Norwood's (Mass.) water comes from 132 tubular wells, 2½″ in diam. and 25′ to 60′ deep. Before '35, red water, poor taste, odor and corrosion all caused trouble. Consultants, after investigation, recommended 2-m.g.d. treatment plant to remove iron and manganese and to correct corrosiveness. Built with P.W.A. aid. Includes aeration basins with nozzles, 2 upward-flow contact units of coke in series, lime mixing basin, settling basin with 93-min. detention period, sand filter in 2 units, and appurtenant pumps. Automatic operation governs whole plant except high-lift pump. One operator provides all needed labor for normal operation.—*Arthur P. Miller.*

The Decolorizing of Water in the Stalin Water Station. P. V. Mozzhukhin and L. N. Shustova. Vodos. Sanit. Tekh. No. 6: 34 ('39); Khim. Referat. Zhur. No. 10: 94 ('39). Water of Stalin station bacterially pure and only slightly turbid, but humus substances give it color and high O consumption. Attempts made to destroy color of water by fractional in-

troduction of coagulant, coagulation of part of water, introduction of coagulant into water in form of dry powder, addn. of ppt. from tank contg. soln. of coagulant, addn. of pure coagulant, clay or lime, activated charcoal, $KMnO_4$, $FeSO_4$ and Cl_2 (with and without coagulant) and preliminary chlorination. Best decolorizing agents are strong oxidizers, particularly Cl_2. Preliminary chlorination with 2.5–3 grams/cu.m. of Cl_2 is most economical method and it permits decreasing amt. of coagulant to 60 mg./liter. Greater decolorization and greater saving in coagulant can be effected by increasing dose of Cl_2 to 6.8–10 grams/cu.m., but with this quantity de-chlorination is necessary.—*C. A.*

Chlorination of Water Supplies. *Questionnaire.* British Water Works Assn. Wtr. & Wtr. Eng. (Br.) **42:** 273 (Aug. '40). Questionnaire was included in annual report of exec. com. of Br. W. W. Assn. Purpose was to secure information concerning use of chlorine in purif. Over 600 replies (97% of home members) were received. 40% of authorities do not chlorinate. Scotland, in general, does not chlorinate. Of 134 authorities replying, with a population of 50,000 and over, only 26 do not chlorinate. Questionnaire was addressed to home counties concerning difficulties in obtaining supplies of chlorine caused by bad weather during winter months, so railway com. might be approached with request that in any future emergency, chlorine should be treated as "food."—*H. E. Babbitt.*

A "Swimmin' Hole" With Modern Fittings. S. W. Sapirie. Eng. News-Rec. **125:** 840 (Dec. 19, '40). Description of Crab Orchard Lake, 7,000 acres in area, near Cardondale, Ill., which will combine natural setting with sanitation facilities of modern indoor pool. Project was designed to large extent on basis of experience at Lake Springfield, where treated water is supplied to bathing area through perforated pipe laid in wooden box containing crushed rock 2′ below sand bottom of lake; chlorine content is maintained between 0.1 and 0.2 p.p.m. in bathing area. To avoid clogging of orifices, which has occurred at Springfield, Crab Orchard plan provides for line of concrete discharge pedestals, spaced 50′ apart, along center of bathing area, marking 3′ depth. Intake tower for system, located just outside bathing area in 15′ of water, is connected by 8″ cast-iron pipe to pumping station which houses 1,000-g.p.m. centrifugal pump, 75-lb. chlorinator and ammoniator. Chlorine will be applied to pump suction and ammonia, equivalent to ⅓ chlorine dosage, to discharge line. Soda ash will be added to maintain pH value between 7.4 and 7.6. Beach zone will have capac. of about 1.5 mil. gal.; 25-hr. operation of pump will supply this amount of treated water. Swimming load capac. is conservatively estimated at 3,000 persons, allowing 25 sq.ft., or 500 gal. of water, per bather. On basis of 20 persons per 1,000 gal. of treated water added, swimming area would provide for turnover of 1,200 persons per hr.—*R. E. Thompson.*

Commercial Ozone. A. E. Williams. The Engr. (Br.) **169:** 557 (June 21, '40). Ozone is an endothermic gas, heat of formation being approx. 33,000 gram-calories per molecule. Besides being produced by some chem. reactions, it is formed by evapn. of water, incandescent bodies, radio-active elements, ultra-violet rays, electrolysis, and electrostatic field. Latter method is one most widely used commercially. Generally accepted that ionization by collision occurs in commonly used, silent-discharge, commercial ozone generator. In ozone generator of solid tubular type, tubular electrodes are fixed coaxially within tubes of glass, latter being surrounded by cooling water, which is also grounded, while appropriate gap is left between outer glass tube and inner metal tube (electrode) to permit air to be passed through. Modern generator permits efficient operation at as low as 25 cycles with voltage which seldom exceeds 5,000. At low ozone concentrations, as used for ventilation, about 300 grams per kw. is obtained, and at very high concentrations, yield is about 150 grams per kw. Among numerous industrial applications of ozone is treatment of water; as, for

example, recent installation at Huntington pumping station of South Staffordshire water works. In general, for expenditure of one unit of electricity 5,000 gal. (Imp.) of water can be sterilized in fairly large installation. Within past few years, many modern swimming pools have been equipped with ozone apparatus. Damaging effects of arcing on switch contacts need not be emphasized. Contacts are available in which tendency to bounce is overcome by arranging for energy of moving contact member to be absorbed by a resilient stationary member.—*H. E. Babbitt.*

The Treatment of Water by Ozone. M. T. B. WHITSON. Surveyor. (Br.) **97:** 279 (Mar. 29, '40). In addition to its valuable property of being able to sterilize water, ozone reduces color, odor, and taste and leaves behind nothing of a deleterious nature. Yet only 4 water supplies in England are ozonized. In France process has been developed extensively. Explanation lies, probably, in conservatism of British engineer and his distrust of any foreign methods. Among objections to use of ozone may be listed: (1) it is difficult to produce; (2) it cannot be obtained pure; (3) large volumes of air have to be dealt with; and (4) it is insoluble. Preceding objections have now been overcome. At present installations are: France, 90; Italy, 14; Belgium, 5; England, 4; Rumania, 3; United States, 2; and Russia, 1. Expts. on control of algae at Knott Hill res. indicate that solution of problem lies in ozonization. Plant is capable of treating 60,000 gal. (Imp.) per hr. Current enters machine at 500 cycles and 20,000 volts. Results from experiments at Knott Hill indicate that: (1) pH should not exceed 7.0 without prior removal of algal growths by screening or more thorough treatment; (2) acid, moorland waters, containing few algal types, may be ozonized directly to reduce bacteria, color, and odor; (3) reduction of color effected by ozone would be valuable in conjunction with slow sand filters and, in some cases, in pressure filters; (4) moorland waters may be safely ozonized if later action of water on lead is attended to by addition of alkali. Cost of process is about 14s 5d. per m.g. (Imp.). Electrical energy used on large number of French plants varies between 45 and 90 watts per 1,000 gal. (Imp.) Ozonization in France has come to stay and writer's opinion is that it deserves more consideration in England. —*H. E. Babbitt.*

Calgon at Baltimore. V. J. WELDE. Ohio Conf. Water Purif. 19th Ann. Rept. p. 102 ('39). At Baltimore, Ohio, well water of 260 p.p.m. hardness, entirely carbonate, is aerated, treated with lime (excess lime is used to reduce fluorides), recarbonated and passed through pressure filters. A great deal of trouble was experienced with calcium carbonate deposition in pumps, valves, regulators and customers' heating coils. Application of 0.5 p.p.m. "Calgon" after recarbonation has corrected these troubles and reduced time required to backwash filters to about one-third. Hardness of treated water is 14–20 p.p.m. higher than it was prior to adopting treatment. About 35,000 gals. per day is supplied to 1,500 people. *Discussion.* D. H. RUPP: At Topeka, Kans., biggest problem is deposition of silica scale, particularly in hot-water coils. Copper coils are especially susceptible. G. B. HATCH: When metaphosphate treatment is commenced, deposition of calcium carbonate does not stop immediately but is gradually reduced; time required to eliminate deposition varying inversely with the concentration of metaphosphate, indicating that a film of metaphosphate is adsorbed on deposited calcium carbonate. In absence of visible solid phase, stabilization of saturated calcium carbonate solutions is believed to be due to adsorption of metaphosphate on calcium carbonate nuclei, which arrests their growth before they attain sufficient size to impart to solution the usual optical properties of colloidal state. Concentrated solutions of metaphosphate should be adjusted to pH 8.5 by addition of alkali to prevent corrosion of iron and steel feeding equipment.—*R. E. Thompson.*

CHEMICAL FEEDING, CONDITIONING AND SEDIMENTATION

The Design of Clarifiers for Water Works. ROBERT WALTON AND THOMAS DOW KEY. Engineering (Br.) **150:** 157 (Aug. 23, '40). Since early times, City of Alexandria has depended for its water supply upon the Mahmoudieh canal, which branches off from Nile below Cairo. Degree and rapidity of change of quality and amount of suspended matter demand alert supervision at all times. Task of purification at Alexandria differs from, and is in some respects more difficult than, that at Cairo. Cumulative pollution between Cairo and Alexandria is converted to lesser known, but more resistant, "protected colloids." If solution of aluminum sulfate is added to water to be clarified, insoluble, gelatinous aluminum hydroxide is formed, the electrical charges on the particles are neutralized and suspended solids are caught up in the aluminum hydroxide to form hypobaric flocculi. Principal aim of all treatment at Alexandria, apart from the elimination of living biological matter, is to effect precipitation in settling basins of clarifiers of 90% or more of suspended matter from incoming water. Systematic work on lab. scale was commenced about 11 yr. ago with study of effects of stirring water, freshly treated with aluminum sulfate with paddles revolving at different speeds in rectangular and circular vessels. To ascertain whether or not disposition of inlet, outlet, and two intermediate walls was conducive to best possible circulation, flow paths were tracked in terms of increased alkalinity, by use of quicklime added at inlet. Decided that best method of attacking problems would be to perform expts. in small glass-sided model of standard settling basin. All experiments were first performed with filtered water and, whenever flow paths were to be observed, solution of potassium permanganate was added to influent, so that color differentiation would be well marked between tinted water and that through which stream flowed or diffused. The conclusions drawn from the work were as follows: (1) Vertical motion and eddies must be prevented if sedimentation of floc particles is to be effective. (2) Horizontal eddies with linear velocities up to 10′ per min. have, for all practical purposes, no floc-supporting value. (3) Critical velocity at which it becomes impossible for floc to settle is function depending largely on character of vertical eddies, if present. Results observed with model in its final form were so promising, especially in manner in which thermomotive changes in flow were obviated, that it was decided to alter one of regular settling basins and to reproduce, as far as possible, same design. Remarkable improvement was noticed in ease of treatment control, purity of effluent, percentage deposition of solids, and aluminum sulfate consumption. In '31, decided to construct new water works on eastern side of Alexandria to: (1) destroy and remove plankton before coagulation and sedimentation; (2) secure adequate and correct addition and mixing of coagulant to plankton-free raw water; (3) assure proper conditioning of freshly coagulated water with view to production of type of floc possessed of qualities most likely to favor rapid sedimentation; (4) cause deposit of greatest possible amount of flocculated suspended matter in clarifiers before water was delivered to filters; and (5) include in clarifiers a means of continuous sludge removal. Agreed that before embarking on construction of full-sized clarifier, best means of ascertaining facts would be to have recourse, once again, to experimental model, diameter of which was arbitrarily fixed at 16′ 5″. Capacity of model was 2,700 gal. (Imp.). Model of conditioner and clarifier combination emerged very successfully from these trials, and it was decided to proceed with construction of 2 clarifiers, each 110′ in diam. With both clarifiers working in parallel at 75% of their rated capacity, has been found possible to shut one out in small interval of time required to close inlet valve and pass whole flow through other clarifier without producing any sensibly deleterious change in effluent, or any necessity for use of higher dose of coagulant.—*H. E. Babbitt.*

Application of Experimental Methods to the Design of Clarifiers for Water Works. R. WALTON AND T. D. KEY. J. Inst. Civ. Engrs. (Br.) **1:** 21 ('39–'40). Water supply of Alexandria obtained from Mahmoudieh Canal which branches off from Nile below Cairo and enters sea at Alexandria. Quality varies considerably and it is necessary to be able to vary treatment at short notice. Large quanties of colloidal material which does not settle easily are present in water. Aluminum sulfate has been found to be most suitable coagulant. Small scale experiments were undertaken at Rond Point Works to determine most suitable design of settling tank. Effect of position of inlets and baffles and temp. of water entering tank on flow of water through tank was studied. Concluded that vertical eddies must be prevented to enable floc to settle, but horizontal eddies do not prevent settlement. Experiments were then made to determine design of baffles which would promote horizontal flow; found that period of detention, originally 40% of theoretical value, could be increased to 80% by modifications in design. Second series of experiments with models was undertaken to design circular settling tank, from which sludge could be removed daily or continuously, for new Siouf works. When radial flow, either outwards or inwards, was used, efficiency of tank was low. Better results were obtained when both inlet and outlet were at periphery and when direction of entry of water was tangential to periphery and water was drawn off over a submerged weir. Position and depth of weir and size of collecting trough had important influence on efficiency of tank. Treatment of water in "floc conditioner" before it entered settling tank further improved results. Full size clarifiers based on this design were put into operation in '35 and have proved entirely satisfactory.—*W. P. R.*

The Clarification of Silt-Bearing River Waters. ANON. Wtr. & Wtr. Eng. (Br.) **42:** 4 (Mar. 11, '40). In past it has been customary to arrange for period of plain sedimentation for 2–3 hr. after passage through mechanical clarifiers, but design of basin and equipment referred to in these notes is such that secondary sedimentation tanks can be dispensed with and clarified water passed directly to rapid filters. Crude silt-bearing water is discharged into flocculator basin equipped with electrically-driven twin rotating mechanical flocculators operating at a speed to assure max. effective use of added coagulant. From flocculator chamber water passes through vertically placed rectangular ports constructed in lower part of wall of basin arranged in such a manner that water is directed into adjacent basin at angle to tangent, water being set into circulation with continuous rotary upward movement. Impurities deposited on floor of clarifier are removed by sludge scraper mechanism which rotates on a peripheral rail carried on wall of tank. A period of 30-min. flocculation, followed by sludge settlement and removal in a clarifier of 3½ hr. water content produces more than 98% removal. Installations in Egypt are described.—*H. E. Babbitt.*

Water Storage at Ashland Aids Treatment of River Supply. J. P. BROWNSTEAD. Eng. News-Rec. **124:** 861 (Jun. 20, '40). Water supply of Ashland, Ky., derived from Ohio R., is highly polluted and is subject to tastes and wide variations in turbidity. Chem. costs have been as high as $28.50 per mil. gal. A 20-mil. gal. preliminary sedimentation basin has just been completed which will hold 10 days' supply. Basin will not only serve as equalizing tank and assist treatment process by removal of settleable material, but will also permit pumping from river to be suspended when taste-producing substances or algae are present. Reservoir was built in natural ravine and is lined with hexagonal concrete slabs, 10′ to side and 5″ thick, joints being filled with hot expansion joint compound. One side of ravine was closed off by earthfill dam with gravity concrete corewall. Cost was $257,000. Purification plant is being rehabilitated and new covered filtered water reservoir is under construction.—*R. E. Thompson.*

Sedimentation and Flocculation. M. B. DONALD. Engineering. (Br.) **149**: 248 (Mar. 8, '40). Relation between sedimentation and flocculation is close. When solids settle in liquids there comes a time when rate of settling drops suddenly from comparatively fast to a relatively slow value. This designated as "critical point." Found that above given concentration solids in a slurry settle with definite top level surface demarking settling solids from supernatant liquid. Gives an easy method of determining settling rate experimentally. Has been pointed out that aggregation, or flocculation, of 1,000 parts into a single floc is likely to increase rate of sedimentation 100 times. Formation of suitable flocs has been object of much research in water works practice where a suitable sized and compact floc is often essential. Further evidence on formation of flocs comes from experiments with sewage and with mud. Fact that flocculation takes place does not eliminate Stokes law from consideration. Accelerated rate of sedimentation for flocculated particles may be due to formation of larger flocs or may be that in more concentrated slurries flocs have formed a loose structure below, this being broken down as more solid is piled upon it from above. Bulk vol. of sand is about 1.67 times its true volume because of percentage of voids in it. As particle size becomes smaller bulk vol. may become proportionally larger. Has been found that correlation exists between sedimentation vol. and value of heat-of-wetting of particular solvent with respect to clay. If this is true it opens up a thermodynamical approach to problems of flocculation. Predominating cause of variation is that sedimentation vol. would appear to be surface film. With regard to relation between wetting and flocculation it is of interest to compare findings of flotation practice. Since substances which can be flocculated can usually be floated, and vice versa, terms flocculated and deflocculated have become more or less synonymous with floatable and unfloatable. Question of structure of flocculated solids also enters into problems of filtration. In determining resistance to flow of filtrate through filter cakes it is found that resistance sometimes increases as more pressure is applied to force filtrate through. Interesting corollary of tendency to variation of sedimentation vol. is variation of amt. of different liquids absorbed by same quantity of solid. Has been postulated recently that substances which are thixotropic, such as bentonite in water, give large sedimentation vol. Thixotropy is state between coagulation and a stable solution. This view of thixotropy would also indicate that it is essentially an intermediate state between flocculation and deflocculation, *i.e.* between small and large sedimentation vol.—*H. E. Babbitt.*

The Effect of Water Hardness on the Formation of Floc From Sodium Aluminate. L. B. MILLER AND R. L. LANZ. Paper Tr. J. **110**: TAPPI Sect. 118 ('40). Effects of concentrations of calcium and magnesium salts up to about 5,000 p.p.m. on floc formation from a solution of 410 p.p.m. sodium aluminate in distilled water were investigated. Calcium hydroxide and magnesium hydroxide do not form precipitates alone until pH values are reached which are well above those used in expts. No solid phase appeared when sodium aluminate solution was titrated with calcium chloride. With magnesium sulfate, opalescence appeared at pH 9.95, when 33 p.p.m. magnesium sulfate had been added; at pH 9.75, floc formation occurred when 82 p.p.m. magnesium sulfate had been added. When the sodium aluminate solution was titrated with acid, floc formation began at pH 9.60. Therefore appears that specific reaction, inducing floc formation, occurs between aluminate and magnesia hardness. When sodium aluminate was titrated with magnesium bicarbonate, floc formation occurred at pH 9.3 after addition of 151 p.p.m. magnesium bicarbonate; appearance of floc was not preceded by opalescence. Results so far obtained are only of a preliminary nature, but indicate that hardness of water may affect flocculation by aluminate.—*W. P. R.*

Coagulation of Natural Waters With Aluminum Sulfate at Low Temperatures. B. A. Skopintsev and M. T. Golubeva. Vodos. Sanit. Tekh. **10:** 45 ('38); Khim. Ref. Zh. **2:** 3: 102 ('39). Authors studied effect on coagulation in water of Moscow River of amount of coagulant, alkalinity of water, mixing of water, presence of turbidity, addition of lime, and addition of alumina, at temps. of 2–4 and 17–19°C. Three most effective methods of obtaining a floc at low temps. and at same time sufficiently purifying water are by stirring, by addition of artificial suspension in form of clay or milk of lime, and by addition of alumina. With second method, care should be taken that no more than exact dose of clay required is added, or clearness of water, after coagulation, will be reduced; an excess of lime causes an increased pH of water and an accumulation of aluminum.—*C. A.*

The Use of Sodium Silicate as an Aid to Coagulation at Lima, Ohio. E. E. Smith. Ohio Conf. Water Purif. 19th Ann. Rept. p. 112 ('39). Sodium silicate is employed to facilitate coagulation, application of 0.21–0.34 g.p.g. reducing amount of alum required from 2.05–2.5 to 0.75–1.3 g.p.g. Silicate is received as 40° Bé. solution, which, after dilution, is introduced into alum solution line. Combined cost was $2.06 per mil. gal. compared with $3.82 when alum was used alone (different period). Treatment increases the pH value and decreases corrosion index.—*R. E. Thompson.*

Sludge Blanket Type Settling Tanks at Shelby. G. A. Hall. Ohio Conf. Water Purification, 19th Ann. Rept. p. 106 ('39). Brief details are given regarding first 3 months' operation of Shelby softening plant. Anticipated that final hardness will be maintained at 120 p.p.m. Detention period in Spaulding precipitator is 60 min. and sludge blanket contains 0.6–1.0% solids. Sludge in concentration tanks contains 8.5–10.0% solids. Hardness was reduced from ave. of 592 to ave. of 215 p.p.m. Ave. dosage and costs, respectively, of chemicals per mil. gal. was: alum, 242 lb., $3.40; Na_2CO_3, 1385 lb., $14.85; CaO (68%) 3710 lb., $17.70.—*R. E. Thompson.*

Columbiana Sludge Blanket Settling Tanks. C. C. Hommon. Ohio Conf. Water Purification. 19th Ann. Rept. p. 108 ('39). Softening plant equipped with sludge blanket settling tanks serving Columbiana (3,000 pop.) reduces hardness from 18–20 (all carbonate) to 3.5–4.0 g.p.g. Lime, without coagulant, is employed for softening. Plant, which has capac. of 300,000 gal. per day, was constructed because of troubles due to deposits in heating coils, one large property owner contributing $1,000 toward project. No operating problems have been experienced.—*R. E. Thompson.*

The Handling of Chlorine at Water and Sewage Plants. J. B. Baty. Can. Engr., **78:** 4: 24 (Apr. '40). Operating difficulties are generally due to improper temp. control, ruptured pressure-gage diaphragms, indiscreet use of lubricants and cleaning fluids, leaving chlorine lines open during shut-down periods, or failure to close valves completely when cylinder is empty. Max. discharge rate for 100–150-lb. cylinders is approx. 35 lb. per 24 hours at 70°F. Temp. of cylinder should never be higher than that of gas lines or chlorinator, otherwise condensation will occur. Fusible plugs in cylinders soften at temp. above 157–160°F. Tray water temp. below 49.2°F. will lead to formation of chlorine hydrate. Cleaning fluids such as grain or denatured alcohol and ether are converted by chlorine into hexachlorethane, a solid waxy substance. Methane solvents—chloroform and wood alcohol—are converted into carbon tetrachloride, which soon vaporizes and causes no trouble. Action of chlorine on oil from ruptured pressure-gage diaphragm results in formation of tremendous volume of "goo." During recent yrs., impurities in cylinder chlorine have been reduced from 0.2% by wt. to max. of 0.01%. Empty chlorine cylinders are thoroughly inspected, cleaned and painted by manufacturer. Valves are completely dismantled and all worn parts replaced. Use of clamps and adaptors on cylinder connections is recommended. Leaks around valve stems may usually be stopped by tightening packing nut. If leak has persisted for some time, packing may have become hard, and

additional well-graphited asbestos packing may be required. If valve is tightly closed and no chlorine is escaping through packing, packing nut may be removed safely. Use of lubricants or greases should be avoided. Leaking fusible plugs must be handled with care. Steel U-clamp, by means of which rubber gasket backed with small coin can be pulled securely on to face of leak, may be employed. Immersing of leaking cylinders in water is not advisable and has resulted in major accidents. Upending of cylinder and allowing liquid chlorine to flow through flexible connection (garden hose will fit) into barrel containing mixture of hydrated lime and water (5 lb. per 10 gal.) is recommended —1¼ lb. hydrated lime will absorb 1 lb. of chlorine completely and without danger. Caustic soda may be used instead of lime. Important factors in chlorine safety are accessibility and movability of cylinders and ventilation of bldg. in which they are housed. Fresh-air vents should be at top of room and discharge ducts at floor level as chlorine is 2½ times as heavy as air. Physiological effects of chlorine are stated by U. S. Bureau of Mines to be as follows: least detectable odor 3.5 p.p.m.; least to cause throat irritation 15.1 p.p.m.; least to cause coughing 30.2 p.p.m.; dangerous for 30-min. exposure 40-60 p.p.m.; rapidly fatal for short exposures 1000 p.p.m. Approved-type gas masks and extra canisters should be available and operators instructed in their use. Carbon dioxide-oxygen method of first aid is important development. By providing abnormal concentration of carbon dioxide in lungs, patient involuntarily breathes deeply. Results obtained are remarkable. Milk is useful in relieving mild cases of throat irritation. Eyes that have been irritated by chlorine should be washed thoroughly with water or weak boracic acid solution (not more than 5%).—*R. E. Thompson.*

Precautions in Transport and Handling of Chlorine. ERNST VON POST. Arbetarskyddet. **1:** 2; **2:** 38 ('39); Ind. Safety Survey (Intern.) **16:** 22. Piping must be of steel. Since liquid chlorine has very high expansion coeff., pipes are likely to burst if temp. rises; therefore, explosion bends should be provided. All containers, piping, etc., should be inspected periodically and premises should have good through ventilation. Water sprays are useful for rendering escaping chlorine harmless. Rooms where chlorine may escape must have at least 2 exits, as far apart as possible. Railway tank cars must have protective roof; metal sheets should be used to reduce movement of liquid chlorine when jolting occurs. Inlet and outlet valves must be protected by strong cover against mechanical damage. Advisable to locate tank car sidings near body of water. Tank lorries should be painted white to afford some protection against sun. All fixed containers should be tested under pressure of 22 atmospheres. Must be protected from exposure to high temp. and should be installed over cemented pit with outlet at bottom, just above body of water, with sprinkler overhead. Leaks in container can be stopped by water spray, which is frozen by evaporation of chlorine. Riveted containers rust readily and should never be used. Water-gas welded containers are best. Klingerite-treated graphite is recommended for packing valves, manometers, etc., and asbestos strips saturated with asbestos for stuffing boxes. Parts exposed to corrosion are best protected by ebonite lining.—*C. A.*

Development of Submerged Combustion for Recarbonation. L. H. SCOTT, Southwest W. W. J. **22:** 2: 22 ('40). Method consists of burning mixture of air and gas some distance under surface of liquid to be carbonated, producing CO_2 gas in very finely divided state and rendering it almost immediate and complete absorption. Burner is cylindrical in shape and installed with longer axis in vertical position. Bottom, or discharge end, is open across entire section; there is a frustro-conical expansion chamber at upper and closed end. Expansion chamber is threaded at point near cone apex to allow union with mixed gas feed lines. That used at Oklahoma City, Okla., is 5″ in diam. and has capac. of 2,000 cu.ft. per hr. of natural gas of 1,000 B.t.u. gases, which are fed at constant pressure

in predetermined proportion, may be varied by one valve control over wide limits to meet variations in water flow. Equipment is fully automatic, both as to change in rate and chemical composition of water, being operated from a pH recorder-controller located down stream from recarbonator. In case of failure, flow of gas is automatically shut off by action of solenoid valve. Advantages of system over conventional methods are: simplicity of equipment, controllability, greater chemical efficiency, trouble-free operation, reduced maintenance, elimination of diffuser and corrosion troubles, and cost equal to or lower than present costs.—*O. M. Smith.*

Aqua Ammonia for Chloramination. C. J. LAUTER. W. W. & Sew. **87**: 306 (July '40). Difficulties with $(NH_4)_2SO_4$ and lower price of NH_4OH, plus recently improved solution feeders suggested trial of NH_4OH at Washington, D. C. Material is purchased in 110-gal. drums. Plant and operating procedures and advantages are described. Costs were reduced by 50%.—*H. E. Hudson, Jr.*

SOFTENING AND IRON REMOVAL

Water Softening. T. E. LARSON AND A. M. BUSWELL. Ind. Eng. Chem. **32**: 132 (Jan. '40). Electrophoresis determinations were made to study charge on colloidal particles of hydrous alumina, hydrous magnesium oxide and calcium carbonate in water treatment. Colloidal hydrous alumina is negatively charged above pH 8.2 and positive below. Above initial pH of 8.2, pH decreases with stirring; below 8.2, it increases. Using aluminum sulfate as source of aluminum, change in pH with aging caused flocculation in pH range 7.6 to 8.2 with basic aluminum sulfate of variable composition as the solid phase. Colloidal particles under these conditions were positive below pH 7.6 and negative above pH 8.2. Colloidal calcium carbonate is negative and magnesium hydroxide positive throughout pH range of water softening. Relatively slow approach to equilibrium as indicated by pH change on prolonged stirring indicates need in water treatment practice for proper mixing and sufficient detention periods. Isoelectric point of water treated depends on source and concentration of aluminum added, on form and amt. of colloidal matter present, and more definitely on amt. and nature of polyvalent ions present. Best results should be obtained when alum floc is not formed before addition of reagent to water being treated.—*Selma Gottlieb.*

Water Softening. JOHN E. SUEDKAMP. Am. City. **55**: 5: 44 (May '40). After 50 yr. of using same well supply of water, excellent in quality but very hard, Hamilton, Ohio, realized need for augmenting it to serve present population of 53,000. Plans were made at same time for an extensive softening plant and improved distribution system. 6 new wells varying in depth from 110′ to 180′ and with 18″ wrought iron casings were sunk. Treatment works includes 2 buildings. Main building contains wash water tank, lab., office, pump and boiler rooms, ash, coal, coke and chlorine rooms and six 1-m.g.d. capacity filters. Chemical building is separate. Has pneumatic unloading system, a unique feature of which is 500′ suction line to unloading siding. Alum and soda ash are used for softening. Back of building are siphon-feed clarifiers and connected to one side are 2 carbonation tanks. There is a coke-burning carbon dioxide producer with a max. capacity of 150 cu.ft. of gas per min. with 12% CO_2. Motor-driven compressor moves artificial gas which is delivered to 7 pipe laterals in each carbonation tank for recarbonating softened water. 2 parallel 24″ iron distribution lines lead out from plant to corporation limit. From this point 1 force main carries supply to business district and to old res. west of the Miami R. and other one is diverted to eastern portion of city and newly

constructed 6-mil. gal. covered res. Both res. (built at exactly same elevation) are pumped until full, when pumping ceases and res. are allowed to carry load until water has dropped several feet. Quality and softness of water since new plant was built have given complete satisfaction.—*Arthur P. Miller.*

Water Conditioning for Greenhouses. C. H. SPURWAY AND C. E. WILDON. Bull. Mich. Agric. Exp. Sta. **166:** 3 ('38). Hard water softened for use in greenhouses by treatment with phosphoric acid which reduces the alkalinity of water, forming calcium hydrogen phosphate and magnesium hydrogen phosphate. These phosphates act as fertilizers, and soil is prevented from becoming too alkaline for good plant growth.—*C. A.*

Effect of Carbonate-Ion Concentration in Water Softening. T. E. LARSON. Ind. Eng. Chem. **32:** 1240 ('40). By use of concepts of solubility product, activity coef. and common-ion effect, the co-solubility of $CaCO_3$ and $Mg(OH)_2$ calcd. to be 20 p.p.m. (as $CaCO_3$). Presence of non-incrustant salts increases solubility, and excess of hydroxyl or carbonate ion decreases it. Known beneficial effect of Na aluminate is due to excess hydroxyl ion formed on hydrolysis and coagulating power of hydrous alumina. Curves derived from equations presented give basis for determining limits of softening but do not give values to be expected in practice.—*C. A.*

St. Paul's New Water Softening Plant. LEONARD N. THOMPSON. Minn. Munic. **25:** 111 (Apr. '40). Delivery of softened water was begun Jan. 7, '40. Advantage was taken of enlargement of McCarron filtration plant to provide for softening by providing flocculators and clarifiers for continuous sludge removal. Trial of softening in '24 led to so much public criticism that it was almost immediately abandoned. Meanwhile public temper has changed. Enlarged treatment plant has capac. of 75 m.g.d., but provision has been made for bringing it to 90 m.g.d. About 90% of water treated is pumped from Mississippi R., passes through a 60″ concrete conduit 7 mi. to a chain of lakes. From lower lake, water flows through a 90″ concrete conduit to filter and softening plant. Original total hardness of 125 to 180 p.p.m. is reduced to about 50 p.p.m. ★[First munic. water softening plant in world was put into use in 1854 by Plumstead, Nodwich and Charlton Consumer's Pure Water Co., operating in the London metropolitan district. 13 years had passed since Thomas Clark, Professor of Chemistry at Aberdeen University had taken out his patent to soften water by lime. Slowness with which his process was adopted, notwithstanding much publicity, is further illustrated by fact that in 1870 only 4 plants had been built for munic. supply. In North America, first munic. softening plant was put into use by City of Winnipeg, Manitoba, July 1, '01; second, by Village of Oberlin, Ohio, Dec. 23, '03. For some years, additions were few and far between. Recently, number has increased rapidly. Total, with geographical distribution, as compiled by H. M. Olson will soon be published]★—*M. N. Baker.*

New Water-Softening Plant Operated Automatically. ANON. Am. City. **54:** 12: 45 (Dec. '39). Considerable iron bacteria growths in the water mains due to the character of the water, prompted the installation of a lime softening plant at Elkhorn, Wisc. Water is supplied by two 1,650-ft. wells. Advantageous feature of the plant is that after first adjustments are made, it operates automatically throughout the water treatment process with a minimum of technical attention. The new concrete and brick building was carefully designed for compactness and convenient machinery arrangement. Plant has capacity of 70 g.p.m., serving a population of 2,340. Aeration removes H_2S and CO_2 is reduced from 45 p.p.m. to 18–24 p.p.m. Hardness of the well water is 308 p.p.m. which is reduced to 70 p.p.m. by the precipitator method with recarbonation and filtration. After recarbonation, water flows to 2 automatic filters. Equipment in pipe gallery includes speed control

for the precipitator which regulates maximum demand at the plant and is timed to be out of step with demands of householders thus resulting in a saving of electricity costs to the city.—*Arthur P. Miller.*

An Old Softening Plant Goes Modern. E. L. FILBY. Eng. News-Rec. **125:** 170 (Aug. 1, '40). Owensboro, Ky., has been served by public water supply since 1878, when private co. started distributing untreated Ohio R. water. In '06, citizens voted $260,000 for municipal system drawing water from thirteen 125′ wells driven to sandrock on river bank. In '11, 3-m.g.d. lime softening plant and wood-fiber filters were installed at cost of $28,380. Water was softened from 15.4 to 3.87 g.p.g. Plant is now being rehabilitated at cost of $600,000. Three gravel wall wells, 125′ deep and 18″ in diam., rated at 750 g.p.m., and capable of yielding 1,000 g.p.m., replace 11 former wells. New wells yield 27% more water and hardness is only 8.5 g.p.g., compared with former 20 g.p.g. Intake is being constructed in Ohio R. to supply water for power plant condensers. By minor changes, intake can be made available as source of raw water for plant. Existing structures were incorporated in new treatment plant, which consists of splash-type aerators for reducing hydrogen sulfide and carbon dioxide, lime feeders, settling basin equipped with mechanical sludge collectors, recarbonation basin using carbon dioxide derived from natural gas, three 20 x 18′ filters of conventional perforated-pipe underdrain type, with 18″ gravel and 24″ sand, and operated at 4 gal. per sq.ft. per min., and chlorinator. Provision has been made for washing filters with surface jets. Following recarbonation, recirculated sludge is added, together with small amount of alum, to aid settlement. For several yr., post-carbonation will be employed to remove excessive lime deposits from distr. system. Special feeders will permit use of hexametaphosphate in case of carbon dioxide failure. Fully equipped, air-conditioned laboratory is included.—*R. E. Thompson.*

Union Pacific Builds Large Water Softening Plant. ANON. Railway Age. **109:** 10: 332 (Sept. '40). Union Pacific R. R. recently completed installation of 60,000 gal. per hr. water softening plant for treating Missouri R. water used at Council Bluffs, Iowa, terminal. Lime and soda ash used for softening, sodium aluminate for coagulation, and an organic corrosion inhibitor is fed into softened water before delivery for distribution. Steel settling tank is 35′ by 72′ with an excelsior filter, and storage tank is 47′ by 69′ holding 890,000 gal. Chemical vat has vertical agitation and a differential chemical proportioner is used. All control is automatic and only labor used is for recharging chemical vats.—*R. C. Bardwell.*

Cold Lime-Soda Water Softening. *Experiences With Spaulding Precipitators.* S. B. APPLEBAUM. Ind. Eng. Chem. **32:** 678 (May, '40). In Spaulding precipitator, sludge is thoroughly mixed with water and chemical, and mixture rises through suspended sludge filter zone with upward water velocity decreasing with increasing height. Height and density of sludge filter are controlled by continuous or intermittent desludging and upward velocity. When water reaches certain height it separates from sludge and emerges clarified and softened. Size of settling tank can be decreased from 3- to 6-hr. to 1-hr. detention, chemicals are efficiently used, recarbonation can frequently be omitted and effluent is softer, clearer and more stable. In Springfield, Ill. plant, design of one cone inside another was adopted. Vertical radial baffles in sludge-filter still currents created by agitators. Minneapolis plant now nearing completion as 12 concrete units of 120 m.g.d. combined capac., similar in design to Springfield plant. Between '37 and Sept. '39, 70 precipitators were installed by Permutit Co., 43 municipal and 27 industrial. In industrial installation in La., capac. of 3 existing vertical steel continuous lime treatment tanks, 34′ diam. x 50′ high, was more than tripled by conversion into precipitators, utilizing great height of existing tanks by double deck sludge filter zone with

common mixing zone. Results were excellent on turbid Mississippi R. water. At Woodstock, Ill., existing lime-soda plant was converted to precipitator type with steel pyramidal funnel inserted into each square tank, and agitator at bottom. Recarbonation was abandoned and, instead, split treatment used, all of lime being added to part of water producing caustic alkalinity but removing magnesium efficiently; caustic effluent then mixed with controlled ratio of raw water. Other designs include: (1) cylindrical concrete precipitators with inner steel double cones and (2) rectangular outer tank with vertical walls, the agitator shaft being horizontal instead of vertical and permitting installation in long narrow basins. Detention time of 1 hr. in precipitator gives reasonable factor of safety. At freezing temps. velocity at top of precipitator of 1.25 g.p.m. per sq.ft. is usually satisfactory and may be increased at higher temps. If magnesium is low, higher flow rates and decreased detention times are possible, since $CaCO_3$ settles more readily than $Mg(OH)_2$. Choice between single stage or split lime treatment is detd. by nature of raw water, treated water analysis desired, and chemical costs involved. Sludge circulates freely through sludge filter zone. Laboratory tests made are (1) detn. of sludge strength by weighing a definite volume and (2) detn. of top of sludge layer by lowering a sampling thief. Sludge is held at concn. of 0.1 to 5% by weight, usually 1 to 2%. In all designs constructed, mixed water is uniformly mixed through sludge filter zone without channeling or short-circuiting. Typical precipitator results show considerably better softening than with former equipment, lime requirement no greater than theoretical, and effluent frequently stable without recarbonation. Though most installations have been for water softening, same design has been adapted to turbidity and color removal with appropriate chem. treatment.—*Selma Gottlieb.*

Theoretical Limits of the Lime-Soda Method of Water Softening. T. E. LARSON AND A. M. BUSWELL. Ind. Eng. Chem. **32:** 130 (Jan. '40). Revised calculations involving Debye-Hückel activity coefficients and common ion effect show that under controlled conditions leading to final equilibrium, lime-soda softening may reduce water hardness to 10 to 15 p.p.m. Sodium aluminate reduces hardness because of its caustic alkalinity and by colloidal coagulating action of hydrous aluminum oxide rather than by precipitation of insoluble aluminates. Small amts. of colloidal silica aid coagulation and are necessary for good coagulation even with excess hydroxyl ion and aluminate. With 30 p.p.m. of silica, coagulation was poor in absence of aluminate.—*Selma Gottlieb.*

Municipal Softening Plant Using Lime and Soda Ash. THEODORE REED KENDALL. Am. City. **55:** 3: 44 (Mar. '40). Well-water supply at Ypsilanti, Mich., having an iron content of 1.6 p.p.m. and 395 p.p.m. total hardness, is rendered consumable by softening with lime to 90 p.p.m. and reducing the iron to 0.3 p.p.m. by filtration and use of soda ash. Thorough mixing of water and chemicals is accomplished by a double treatment, first in one mixing chamber, then in another having similar equipment. Water then passes outside building to primary settling tank, over 4 weirs into flume for recarbonation and on to secondary settling. Filtration follows settling. Recarbonization equipment is complete plant in itself, designed for burning artificial gas in a special retort to produce max. amt. of CO_2 gas. Interesting feature are steel weir edges of wash-water troughs, set very accurately so when water first breaks over edge, it does so simultaneously for entire length of 2 troughs in filter. Weirs are bolted to base troughs and supported at mid-length by rods from above to insure even-ness. Construction of plant presents attractive appearance both outside and in; equipment is installed to make for high efficiency in operation and an added benefit is bright illumination around filters obtained by use of glass blocks for windows.—*Arthur P. Miller.*

Lime Water-Softening at Granite Falls, Minn. ANON. Am. City. **55:** 1: 44 (Jan. '40). Water softening plant at Granite Falls, Minn. reduces hardness of the raw water from the Minnesota R. from a max. of 1026 p.p.m. to below 170 p.p.m. When the river water contains comparatively little hardness, plant is used only for filtration. Soda ash, lime and alum are added for softening. Activated carbon and pre-chlorination are utilized seasonally for odor and algae control.—*Arthur P. Miller.*

Zeolite Water Softening at East Lansing, Mich. RAYMOND J. FAUST, Am. City. **55:** 4: 62 (Apr. '40). Two successive undertakings (first having proved inadequate) to increase water supply and improve its quality have resulted in noteworthy progress in water-conditioning in East Lansing. First plant built in '33 had capac. of 1 m.g.d.; newer plant, placed in service in Nov., '39, has capac. of 1.44 m.g.d. and is equipped with only 3 softening and 1 iron-removal unit, as compared with 5 and 2 respectively of '33 project. Zeolite is used for softening and reduces total hardness of 320 p.p.m. of raw water to 58–68, and iron content of 1 p.p.m. to not more than 0.15. Also, one of specifications of latest plant is that hydrogen-ion concentration of treated water be not less than 7.6. To avoid corrosive water due to total elimination of hardness by zeolite, split-treatment method is used whereby 75% of water passes through zeolite units for both softening and iron removal and 25% passes through only iron-removal unit. Combination of treated water from both processes yields above specified low iron content and total hardness. To raise pH above 7.4, caustic soda is applied to treated water. —*Arthur P. Miller.*

The Application of Ion-Exchanging Artificial Resins to the Removal of Salts From Water. A. RICHTER. Angew. Chem. (Ger.). **52:** 679 ('39). Method for removal of salts from water is described, in which various types of artificial ion-exchanging resins known as "Wofatit" are employed. To effect partial removal of salt, part of raw water is passed over hydrogen-exchanging Wofatit and remainder over sodium-exchanging Wofatit in ratio corresponding to ratio between bicarbonate and neutral salt present in raw water, and controlled by analysis of mixed treated water. When treated waters are mixed, sufficient mineral acid is present to effect destruction of sodium bicarbonate present in neutral softened water; in this way softened water free from bicarbonate and mineral acid can be prepared. Should a completely acid-free water be required, a "buffer filter" containing an exchanging resin of *C* type may be placed after these filters. Complete removal of salt is a two-stage procedure. In first stage metallic ions are exchanged for hydrogen ions by resin which is regenerated with hydrochloric acid; in second stage, acid radicals are exchanged for hydroxyl ions from an hydroxyl-exchanging resin which is regenerated with sodium hydroxide or sodium carbonate. Complete removal of salt can be achieved only when anions can be passed to second filter in form of the free acid; therefore necessary to choose resin such as Wofatit K, with high and, as far as possible, constant acid strength for first filter. Bivalent anions are more easily removed than univalent anions. Carbon dioxide has practically no effect on hydroxyl-exchanging resin. In course of each run, pH value of water delivered from filters varies considerably with variations in exchange activity of resins; "buffer filter" containing cation-exchanging resin of medium acid strength, such as Wofatit C, A, or P, which exchange hydrogen ions for sodium ions, should be included. This filter does not need regeneration. Examples are given showing degree to which salt can be removed from water. In one case, an installation comprised 3 filters, containing 370 liters of Wofatit K as hydrogen-exchanger, 370 liters of Wofatit M as hydroxyl-exchanger, and 200 liters of Wofatit A as a buffer resin; this installation delivered 2 cu.m. of water per hour. Layout of large plant treating 15 cu.m. per hr. is described. Plant treated river water, which had first been treated with ferric chloride, and gave satisfac-

tory service over a period of 18 mo. After removal of silica by separate process, water yielded by this plant was suitable for use in high-pressure boilers. Same raw water was treated in smaller plant delivering 2 cu.m. per hr. in which removal of salts was accomplished at temps. of from 80 to 85°C.; resins successfully resisted these temperatures. Example is quoted in which mixture of 4 parts of sea water and 96 parts of condensate was treated. After double treatment, chloride was reduced from 760 to 2 mg. per liter, sulfate was eliminated, and dry residue was reduced from 1,400 to 13 mg. per liter. Residue consisted finally of sodium bicarbonate which could have been converted into free carbon dioxide by use of small additional hydrogen-exchanging Wofatit filter.—*W. P. R.*

Reducing Magnesium Hardness. Joseph E. Young. Am. City. **55:** 6: 54 (June '40). Otter Tail River has served as source of supply for Fergus Falls, Minn. since 1883. At certain times of year, however, water was almost unfit to use because of taste and odor. Alkaline hardness varied from 180 to 250 p.p.m., greater part of it caused by carbonates and bicarbonates of magnesium. 2 yr. ago, study of question was started, resulting eventually in purification and softening equipment being installed. Major treatment equipment includes 2 precipitator tanks with recarbonation chamber between them. On floor over recarbonation chamber are 4 dry feed chemical machines fed from hoppers leading to roof level where chemicals are stored. Hose lines from feeders convey chemicals to raw water entrance at end of recarbonation chamber. Opposite precipitators are 4 filters with clear well beneath. Sludge concentrator is at end of pipe gallery which separates filters and precipitators. Plant can be operated automatically although that has not been done. Precipitators can be used in series or in parallel and split treatment can be had by proper adjustment of valves. Latter method of functioning has been found to give most satisfactory and economical results. Final product of new plant varies only slightly from 70 p.p.m. hardness, is clear, sparkling and free from bacteria, with a threshold odor of about 2.6.—*Arthur P. Miller.*

FILTRATION

First Year's Experiences at Cincinnati's New Filtration Plant. Clarence Bahlman. Ohio Conf. Water Purif. 19th Ann. Rept. p. 48 ('39). Cincinnati's purification plant, reconstructed at cost of $3,250,000 to provide capac. of 200 m.g.d., in full operation since Sept. '38. Power is provided by water turbines, variations in load being automatically absorbed by tie-in with local electric utility. Pneumatic chem. conveyor required some adjustments and replacements but now working satisfactorily. Caking of iron sulfate largely eliminated by specifying "overdried" product containing not less than 105% $FeSO_4 \cdot 7H_2O$. Slight hardening of material controlled by dropping concrete vibrator on flexible hose into bin. Accuracy of "Omega" gravimetric feeders usually within 2%. Instantaneous mixing effected by hydraulic jumps. Flocculator paddles operated at peripheral speed of about 1 ft. per sec. Excellent flocculation obtained and most of floc settles in first of 2 clarifier compartments. Turbidity of filter influent rarely exceeds 4–5 p.p.m. Each basin equipped with its own hydraulic jump and direct comparisons of different treatments may be made. Effectiveness of alum and iron sulfate thus compared. The 2 flocs settled equally well but iron floc was larger and less fragile. Better bacterial removals obtained with iron sulfate, but probably due to higher pH values. Alum gave slightly better color removal. 4-fold increase in dosage of either alum or iron sulfate did not improve filter runs when excessive no. of algae were present. Copper sulfate (0.6 p.p.m.) increased length of runs but decrease in algal population rendered expt. inconclusive. Latter treatment resulted in higher bacterial counts throughout plant, except in chlorina-

ted water. Softening does not require immediate consideration. Industrial consumers do not complain unless hardness exceeds 150 p.p.m. for few successive weeks. Lecture room seating 50 or more included. Lab. air-conditioned and distilled water piped to benches from tin-lined tank. Water from various points in plant may be drawn from taps located in lab. Filters may be washed at high rate every 12 min. Rise of 26″ per min. now being used, giving sand expansion of about 45%. Chironomus flies still present. Water of better bacterial quality being produced, notwithstanding greater raw water pollution. Ave. coliform index of chlorinated water was 0.16 per 100 ml.—*R. E. Thompson.*

Chicago's South District Water Filtration Project. ARTHUR E. GORMAN. J. Western Soc. Eng. **44:** 275 (Dec. '39). Filtration of Chicago water first proposed in 1863. Sanitary and industrial pollution of Lake Michigan from Indiana towns has heavily polluted water for South District. Typhoid fever death rate in Chicago declined from 73 per 100,000 population in 1867 to 0.2 per 100,000 population in '39. Bad epidemics in 1872, 1881, 1891, 1892 with a highest death rate (174) in 1891. Complete chlorination of water Dec. '16 reduced rate immediately from 5 to 1.5. Metering program necessary to keep down cost of filtration and designs based on 178 g.p.d. per capita. Present filtration project started with experimental plant in '27 under J. R. Baylis. Plant furnished data for design, and free distribution of filtered water from it educated public on value of filtration. Plant now under construction on lake front at 79th St. Lake front site selected in preference to land site because of availability of publicly owned space, short inlet and filtered water connections needed, railroad siding available, lower excavation costs to keep plant on existing hydraulic levels. Estimated average chemical dosages, in lb. per mil. gal.: alum or iron, 56.7; lime, 104.0; carbon, 58.3; chlorine, 5; ammonia anhydrous, 1.7; ammonium-sulfate, 6.7; sodium silicate (42° Bé) 41.7; sulfuric acid, 4.2. Design of plant has changed hands and, as being built, differs from earlier plans. Principal differences: construction of rubble breakwater instead of cellular type with steel sheet piling; cofferdam of riprap with clay core and single row of steel sheet piling instead of cellular type construction; use of existing Dunne crib intake in place of shallow direct intake originally proposed. Temporary direct intake necessary in any event during construction and additional cost is small to make it permanent. Top of direct intake would have been only 9.5′ below surface at low water. Estimated savings in pumping costs would pay for dismantling existing cribs and eliminate maintenance expenses. Average analyses of water from bottom of crib which is 2,000′ from shore, and proposed intake location, from Apr. '37 to Mar. '39 were as shown in Table 1.

TABLE 1

Average Analyses of Water

LOCATION	TEMP.	COLIFORM ORGANISMS PER 100 ml.	TURBIDITY	ODOR THRESHOLD POINT	
				COLD	HOT
	°F.		p.p.m.		
79th St. Intake.....	47.1	314	20.0	2.9	9.8
Dunne Crib	49.0	42.2	10.1	1.3	5.3

79th St. intake affected by proximity of large sewer discharge into lake which would be prohibited when plant was put in use. Cost of treatment and filtered water quality practically same with either intake.—*R. Hazen.*

A New Filtration Plant in the Maritimes. MAXIM T. GRAY. Can. Engr. **78:** 11: 7 (Nov. '40). Description of purification plant constructed in Sussex, N. B., to treat colored Wards Creek water, formerly used after chlorination only. Plant consists of radial-flow mixing chambers (4 in series) and sedimentation basins, providing 30 min. and 4-hr. retention, respectively, two

8′ x 10′ rapid sand filters and 50,000-gal. clear well, capacity being 0.38 m.g.d. Mixing chambers and sedimentation basins are in duplicate. Filter underdrains consist of 6″ wrought-iron pipe with 2″ galvanized laterals at 12″ intervals. Laterals are tapped at 3″ centers with ¾″ holes, staggered at 45° angles on lower side, and are connected together at ends by ½″ pipe. Latter eliminates concentration of pressure at ends of laterals when backwash pump is first placed in operation and gives very uniform distr. of wash water. Effluent trap establishes uniform head between influent and effluent. Coagulation is effected with black alum and lime. Water is pumped to 0.25 mil. gal. (1 day's requirement) reinforced-concrete reservoir on mountain side. Citizens are pleased with vast improvement in quality of water supplied. Cost of filtration plant, including pumps, motors and equipment, was $22,000, and total cost of project was within 5% of estimated cost of $33,000.—*R. E. Thompson.*

Modern Filter Plant Treats 100 Gallons per Minute. ANON. Pub. Wks. **71:** 6: 24: (June '40). Filtration plant at Clarkesville, Ga. (pop. 617) among those recently constructed plants which treat all of Ga.'s 82 surface supplies. Water taken from Soque River, treated with alum and lime (arranged for pre- and post-application), mixed in chamber 27′ long, 2′ wide and 10′9″ deep with retention of 30 min., settled in 27′ x 18′ x 10′ deep basin, and filtered through single filter 8′6″ x 6′ containing 18″ gravel and 27″ sand, stored in covered clear well 30′ diam. 10′ deep. Daily consumption about 42,000 gal. Raw and filtered water analysis respectively: pH 6.6 to 6.8, 8.2; alk., 10, 25; turb. 45 to 800, less than 5; CO_2, 5.—*Martin E. Flentje.*

Flocculation and Filtration of Water in Industry. E. DESROCHES. Chim. & Indus. (Fr.) **42:** 954 ('39). Discusses removal of colloidal matter from water by filtration. As it is impossible to construct, by mechanical means, a sufficiently fine filter, it is necessary to use coagulated colloid which may have to be provided with a support such as cotton cloth, porous pot or ebonite, or sand. Water usually requires conditioning before filtration, otherwise one of three troubles usually occurs: effluent is at first clear and later becomes cloudy, or it is clarified hardly at all, or yield is rapidly reduced owing to choking of filter. First trouble is due to presence of unstable compounds, such as iron or manganese compounds, which break down when volatile acids are removed on exposure to air. By aerating water before filtration compounds are precipitated and filtered out. When effluent is only slightly clarified, coagulants such as aluminum and iron salts should be added. To avoid choking of filter, experiments must be made to find method of treatment suitable to particular water. Slow sand filters, rapid sand filters, and filters containing porous bodies and cloths are described. Although possible to obtain sterile water by filtration, always danger that breaks will occur in membrane and permit passage of bacteria. Therefore advisable to disinfect water with chlorine or hypochlorite.—*W. P. R.*

Filter Operators' Difficulties in Warm Weather. *Round-Table Conference.* Can. Engr. **78:** 9: 23 (Sept. '40). G. H. STRICKLAND: During first 5 yr. operation of Windsor Utilities Com. plant, short runs due to algae were problem. In June '27, ave. length of run was 5 hr. 20 min., with min. of less than 2 hr., and wash water used averaged 9.6% of water filtered. "Bumping" gave temporary relief but led to formation of mud balls. Substitution of ferrous sulfate and lime for alum extended runs to min. of 10 hr. Effluent was satisfactory, although it had less sparkle. Approx. 15% more wash water was required than when alum was used. Method, however, was more expensive and search for remedy was continued. In '30, pre-chlorination immediately increased runs 100%. Following yr., use of ammonia in conjunction with pre-chlorination was adopted. Algal growths on filter walls, etc., are controlled by spraying with hot copper sulfate solution. Formation of mud

balls has been controlled by modified washing procedure, consisting of: primary expansion for 15 sec.; scrubbing action at half full expansion (10″ rise) for 4 min.; secondary expansion for 15 sec.; and cleaning action at full expansion (18″ rise) for 4 min. D. H. MATHESON: At Hamilton, plankton reaches max. at water temp. of about 50°F., marked reduction occurring as temp. rises to 70°. Filter runs also reach min. at about 50°F. and then increase. During period of short runs, great deal of air is found in filters after run, probably due to plankton forming impervious mat on surface of sand and pressure being reduced under mat. Bumping releases entrapped air and "bumped" filters often run longer than clean ones. Amount of coagulant required to remove plankton by coagulation is too great to be economical.—*R. E. Thompson.*

Gravity Filters. *Washing Operations.* ANON. W. W. Inf. Exch., Canadian Sect., A.W.W.A. **3:** A: 2: 4 (Oct. '40). Tabulated data regarding filter washing in Canadian municipalities given. Runs vary from 4 to 96 hr., rate of wash from about 4″ to 40″ vertical rise per min., length of wash from 3 to 25 min., and percentage of wash water from 0.015 to 17%. Capacities and locations of wash water tanks are included in tabulation. *Wash Water Troughs. Ibid.* **3:** A: 3: 7 (Oct. '40). Tabulated data on plants. No. of troughs per filter varies from 2 to 10, spacing from 3′ 3″ to 8′ c. to c., and distance from sand surface to top of trough from 11″ to 42″ (50″ in Toronto drifting sand plant). Troughs are of cast iron in 36 plants, steel in 9, concrete in 4 and wrought iron in 2. Air-water wash is employed at 27 plants. Data regarding cross-section of troughs included. *Capital Costs. Ibid.* **3:** A: 4: 10 (Oct. '40). Tabulation of capital costs of treatment plants and accessories (exclusive of high lift pumping stations). Cost per capita varies from $2.31 to $43.10, cost per mil. gal. of capac. from $23,800 to $224,000, and cost per sq.ft. of sand area from $4.72 to $512.00. Total cost of various plants included in tabulation. *Mixing Tanks. Ibid.* **3:** A: 5: 13 (Oct. '40). Data on mixing facilities tabulated under following headings: (1) type of mixing, and (2) no., dimensions and capac. of tanks, and mixing period. Mechanical mixing is employed at 9 plants, spiral mix at 11, baffles at 28, and "Aeromix" at 1. Pumps are utilized as mixing devices at 3 plants. Mixing period ranges from 3 to 90 min. *Coagulation Tanks. Ibid.* **3:** A: 6: 16 (Oct. '40). No., dimensions and capacities of coagulation basins at filter plants are tabulated, together with retention period provided and type of filter control valves. Retention period varies from 28 min. to 24 hr. Filter valves are hydraulically operated at 32 plants and manually at 24: both types are employed at 3 plants.—*R. E. Thompson.*

RECTIFICATION

Referring to an abstract (**Flow of Liquid Through Porous Media.** ERIK G. W. LINDQUIST. Teknisk Tidskrift, Uppl. E. (Sweden) **70:** 49 (Apr. '40)) which appeared in the November issue of the JOURNAL (Jour. A.W.W.A. **32:** 1954 (1940)) Messrs. Hulbert and Feben have written to point out that the utterly wrong impression, that their paper, "Hydraulics of Rapid Filter Sand" had neglected to take into account the factor of porosity, might easily be gathered from the information printed. In *Water Works Engineering,* which Lindquist cites, the paper was published in three installments; and, inasmuch as the authors reserved the consideration of porosity to the last part of their paper, it is evident that the final installment never came into Lindquist's hands. Reference to the publication of the paper in the JOURNAL (Jour. A.W.W.A. **25:** 1 (1933)) will show that, mistakenly, Formula (4), instead of Formula (5), was regarded as concluding the paper. A supplementary note dealing with porosity also appeared at a later date (Jour. A.W.W.A. **26:** 271 (1934)). The abstractor gladly takes this opportunity to express his regrets for allowing the error to pass unnoticed.—*Frank Hannan.*